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ZEEMAN EFFECT AND SPECTRAL TERMS IN THE ARC SPECTRUM OF PLATINUM

By A. C. HAUSSMANN

ABSTRACT

Zeeman effect.—The Zeeman effect of 173 platinum arc lines has been investigated in the region 5500 to 2500 A, a field of 33,000 gausses and high-dispersion spectrographs being used. It was possible to *identify 33* of these *lines from their patterns*. The *g-values* are found to be usually *abnormal* and the patterns sometimes *unsymmetrical*.

Spectral terms.—From the Zeeman patterns, intensities in combinations and Meggers' absorption spectra, *12 low levels have been identified*. The *grundterm* is $^3D_3$, d^9s. The assignment *agrees well with* the prediction of the *Hund theory*. There are 72 levels altogether, divided into 12 *low*, 45 *intermediate*, and 15 *high* levels. An attempt is made to identify the intermediate levels from intensities in combinations but no multiplicity is given. To combinations between these 72 levels, there are attributed 376 lines. *These account for practically all the strong lines in the arc spectrum.*

The platinum spectrum has been the object of considerable spectroscopic investigation of late. W. F. Meggers[1] has measured the spectrum from 4498 to 8762 A and has added a large number of lines not previously found. Meggers and O. Laporte[2] have investigated the spectrum of the spark under water. In this they discovered 114 lines absorbed, many of which are those reversed in the arc emission spectrum. L. H. G. Clark and E. Cohen[3] have observed 37 lines in the under-water spark spectrum. These lines are practically the same as those observed by Meggers. J. C. McLennan and A. B. McLay[4] have developed an extensive scheme of wave-numbers.

Of older work we have a few constant differences pointed out by

[1] *Scientific Papers of the Bureau of Standards*, **20**, No. 499.

[2] *Physical Review*, **28**, 642, 1926.

[3] *Transactions of the Royal Society of Canada* (3d series), **20**, 1926. [4] *Ibid.*

H. Kayser[1] and a large number due to E. Paulson.[2] The Zeeman effect of a few of the stronger platinum lines has been studied by J. E. Purvis.[3] Snyder[4] had worked out a fairly complete system for platinum in October, 1900.

In view of the discrepancy between Meggers and McLennan in the assignment of l-levels to the lower terms, it was deemed advisable to obtain the Zeeman patterns for the stronger lines in the region from 5500 A down, as this was thought to be the best way to come to a final decision.

The magnet used was that designed and described by G. H. Carragan[5] in his work on the Zeeman effect in fluorine. It was capable of giving a maximum field of 37,000 gausses with a 6-mm face of pole and a 3.5-mm gap when fed with 9 amp from the 110-volt service line. For convenience in operation and to insure greater homogeneity in the field, a 10-mm pole face and a 4-mm gap were used in most of the investigation. Used thus, the maximum field obtained was 33,000 gausses. The field was determined from the zinc triplet λ 4680.38, λ 4722.34, λ 4810.71 by means of the formula $\Delta\nu_{\text{norm}}=4.7\times 10^{-5}H$.

The platinum was burned in the arc in a Back chamber. A platinum rod 3 mm in diameter was turned into the form of rivets, and these were riveted into brass strips which fitted into the electrode holder. The platinum was made negative, and the positive electrode consisted of a silver strip. Many other materials were tried besides silver, but it was found that the silver produced the steadiest and most economical arc.

The arc was fed by the 110-volt power line at 2–3 amp with a small inductance in series to steady the arc. At this current, the platinum tips lasted about one hour, and very few silver lines were found on the plates. After various pressures in the arc chamber had been tried, it was found that the best results were obtained when the arc was run in air at atmospheric pressure. The arc in vacuum was very feeble, and so much heat was generated that the platinum tips

[1] *Abhandlungen der preussischen Akademie der Wissenschaften zu Berlin*, 1897.

[2] *Annalen der Physik*, **46**, 698, 1915.

[3] *Transactions of the Cambridge Philosophical Society*, **20**, 193, 1906.

[4] Unpublished. Quoted from Meggers and Laporte, *loc. cit.*

[5] *Astrophysical Journal*, **63**, 145, 1926.

would not last longer than ten minutes. In addition, the vacuum arc suppressed the arc lines, enhanced the spark lines, and caused many nitrogen bands to appear.

The exposures were taken with two spectrographs. The second, fourth, and sixth orders of the 10-inch plane grating in a 30-foot Littrow mounting, giving a dispersion of from 1.15 A per millimeter in the second order to 0.25 A per millimeter in the sixth order, were used from 5500 to about 3500 A. A 21-foot concave Rowland grating, having a dispersion of 1.31 A per millimeter in the second order, was used in the second, third, and fourth orders to cover the entire spectrum from 5500 to 2500 A.

A Wollaston prism was used to separate the π- and σ-components. This was quite effective on the Littrow, but on the Rowland, due to the astigmatism, the π- and σ-components were not completely separated, especially in the higher orders. The exposures varied from twenty-six hours in the sixth order of the Littrow to six hours in the second order of the Rowland.

The notation, due to H. N. Russell and F. A. Saunders,[1] which is coming into universal use, is adopted. S, P, D, F, G, ... , refer to the levels with the resultant azimuthal quantum number $k=1, 2, 3, 4, 5, \ldots$, respectively. The multiplicity is denoted by a superscript in the upper left corner and the resultant quantum number j is given by a subscript in the lower right corner. The type of electron is denoted by lower-case letters, s, p, d, f, ($k=1, 2, 3, 4$; $l=0, 1, 2, 3$, respectively). When more than one electron is responsible for the spectral term, the number of equivalent electrons is given by a superscript in the upper right corner, none being used in case there is only one electron of a type. For example, d^9s means nine equivalent d-electrons and one s-electron. If one of the electrons is in an excited state, this fact is denoted by putting a dot between the excited electron and the rest of the configuration.

By convention, two sorts of terms are distinguished. Even terms, (l sum even) give rise to terms of the sort S, $\overline{\mathrm{P}}$, D, $\overline{\mathrm{F}}$, G, ... , and odd terms (l sum odd) give rise to terms of the sort $\overline{\mathrm{S}}$, P, $\overline{\mathrm{D}}$, F, $\overline{\mathrm{G}}$, ... It is understood that the various quantum numbers used are really the vector sums taken over all the electrons entering into the

[1] *Ibid.*, **61**, 38, 1925.

configuration. On the theory outlined we are able to calculate terms that are to be expected from any atomic configuration. Tables of possible low terms for any configuration and rules for determining the values are to be found in F. Hund's[1] book.

In the notation that has been outlined, Landé's splitting factor g is given by

$$g=1+\frac{j(j+1)+s(s+1)-l(l+1)}{2j(j+1)}$$

The values of g and methods of interpreting the Zeeman patterns can be found in Back-Landé.[2]

In addition to the Zeeman patterns, use was made of the absorption spectrum, the well-known intensity rules, and the selection rules, in order to interpret the spectrum. All wave-lengths and intensities longer than 4498 A are those contained in Meggers' paper.[3] Shorter than 4498 A, the values were taken from Kayser's tables, except that Exner and Haschek's values were used to fill in where Kayser listed no lines. The lines from these authors were reduced to international units by means of Kayser's tables. The wave-number was obtained from Kayser's *Schwingungszahlen*.

Altogether, 175 lines were examined for their Zeeman effect. These are listed in Table I. The components are given in decimal fractions of $\Delta\nu_{\mathrm{norm}}$, and the π-components are in parentheses. Most of the lines appear as triplets only. This can be due either to too weak components or to lack of resolving power. Many of the patterns were found to be perturbed so they were no longer symmetrical. This cannot be of the nature of a Paschen-Back effect as the level separations are much too large to permit this. The g-values were often found not to be those in Landé's tables; however, they were sufficiently near in many cases to allow of the identification of the levels. The outstanding exceptions are $^3F_2$ and $^3P_2$. These had g-values of 0.92 and 1.20, respectively, instead of 0.67 and 1.50. They have, however, very nearly the same g-sum as if they were regular. This might be expected as they originate in the same term of the ion. It will be noted that the g-value of $^3P_2$ is almost the same as that of $^3D_2$. These two levels are almost interchangeable, and a de-

[1] *Linienspektren und Periodisches System.*

[2] *Zeemaneffekt und Multiplettstruktur.*

[3] *Loc. cit.*

TABLE I

Observed Zeeman Patterns

λ (Air)	Zeeman Pattern	λ (Air)	Zeeman Pattern
5478.50	(0), 1.33	4437.31	(0), 1.28
5475.78	(.32), 1.26	4430.24	(0), 1.10
5390.80	(0), 1.38	4414.28	(0), 1.55
5387.88	(.45), .88	4411.43	(0), 1.34
5368.99	($\bar{0}$, .27, .55), 1.73*	4364.46	(0), .80
5328.60	(0), 1.03	4358.36	(.22), 1.09
5324.59	(0), 1.51	4343.70	(0, .57), 1.15, 1.74
5319.34	(0), 1.05	4334.70	(0), .95
5301.02	(0), 1.15	4327.07	(0), 1.37
5260.86	(0), .81	4309.18	(0), 1.51
5257.48	(0), 1.29	4304.91	(0), 1.10
5227.66	(.36), 1.29*	4290.97	(0), 1.10
5199.26	(0), 1.05	4288.08	(.23), .90*
5193.91	(0), 1.03	4281.78	(0), 1.21*
5130.91	(0), .50*	4269.25	(0), 1.03
5118.44	(0), 1.00	4263.53	(0), 1.04
5108.45	(0), 1.10	4259.97	(0), 1.57
5095.82	(0), 1.08	4251.16	(0), .88
5082.35	(0), 1.12	4201.14	(0), 1.06
5059.50	(0), 1.24	4192.43	(0), 1.16*
5033.54	(0), 1.15	4164.54	(.36), .92, 1.41*
5002.65	(0), 1.34	4118.69	(0, .60), 1.42, 1.67
4997.98	(0), .95	4081.48	(0), 1.29
4940.15	(0), 1.15	4065.94	(.37), 1.25
4879.55	(.31), 1.23	4054.78	(0), 1.21
4862.40	(.33), 1.17	4000.72	(0), 1.05
4853.93	(0), 1.50	3996.59	(.51, $.\overline{92}$), .42, $.\overline{92}$, $\overline{1.41}$,
4831.97	(0), 1.26		1.90*
4772.32	(0), 1.37	3966.35	(.53), 1.52
4768.12	(0), .79	3953.63	(.75), 1.56
4737.57	($\bar{0}$, .50), $.\overline{50}$, 1.02, 1.52*	3948.38	(.34, $.\overline{73}$), $.\overline{73}$, $\overline{1.20}$,
4684.10	(0), .86*		1.58*
4657.95	(0), 1.46	3925.34	(0), 1.33
4650.07	(0), 1.15	3922.97	(0), 1.34
4640.82	(0), 1.13*	3910.90	(0), 1.23
4577.42	(.35), 1.2*	3906.27	(0), 1.02
4560.07	(0), 1.14	3898.74	(.36), 1.36
4554.59	(0), 1.35*	3819.88	(0), 1.08
4552.42	(.36), 1.2	3818.69	(0), 1.36
4523.00	(0), 1.23	3720.74	(0), 1.15
4520.91	(0), 1.20	3706.54	(.41), 1.04
4515.66	(0), 1.61	3699.89	(.44), $\overline{1.27}$, 1.61*
4498.75	(0), 1.13	3687.45	(0), 1.36
4493.16	(0, .57), 1.12, 1.75	3683.02	(0), 1.54
4486.73	(0), 1.23	3674.05	($\bar{0}$, .60), 1.15, $\overline{1.76}$*
4484.72	(0), 1.20	3672.00	(0), 1.00*
4481.64	(0), 1.42*	3668.39	(0), .98
4480.33	(.63), 1.29	3663.09	(0), 1.18
4473.45	(0), 1.36	3652.26	(0), 1.35
4465.13	(.31), 1.24	3643.16	(0), 1.16
4458.65	(0), 1.04	3638.78	(0), 1.20, 1.80
4457.06	(0), .92	3628.84	(0), 1.30
4445.56	($\bar{0}$, .88), .45, 1.39, $\overline{2.21}$*	3628.11	(0), 1.34
4442.52	($\bar{0}$, .33, .68), $.\overline{33}$, .68,	3610.91	(0), 1.01*
	1.04, 1.36, 1.69*	3587.38	(0), 1.49*

TABLE I—*Continued*

λ (Air)	Zeeman Pattern	λ (Air)	Zeeman Pattern
3485.27	$(\bar{0}, .38), .88, \overline{1.25}$*	2905.90	(0), 1.10
3483.42	(0), 1.43*	2897.89	(0), 1.26
3464.43	(0), .81	2893.87	(0), 1.66
3427.94	(0), 1.16	2893.26	(0), 1.00
3421.72	(.29), 1.02	2888.20	(0), 1.15
3417.05	(0), .87	2870.47	(0), 1.51
3343.90	(0), .48	2839.23	(0), 1.34
3323.80	(0), 1.60	2830.29	(0), 1.52
3315.03	(0), 1.72	2818.23	(0), 1.23
3290.20	$(\bar{0}, .86), 1.36, \overline{2.27}$*	2803.22	(0), 1.04*
3268.38	(0), 1.28	2794.20	(0), 1.42
3261.67	(0), 1.00	2793.28	(0), 1.28
3261.08	(0), 1.29	2773.99	(0), 1.45
3259.72	(0), .93	2773.28	(0), 1.28
3255.93	(0), 1.13*	2771.65	(0), 1.12
3251.97	(0), .46*	2754.90	(0), 1.33
3250.33	(0), 1.39	2747.59	(0), 1.21
3240.20	(0), 1.03	2738.45	(0), 1.17
3230.29	(0), 1.17	2733.96	(0), 1.20
3204.06	(0), 1.31	2719.02	(0), 1.42
3200.69	(0), 1.13	2713.09	(0), 1.65
3156.56	(.60), 1.10*	2705.88	(0), 1.51
3064.69	(0), 1.25*	2698.40	(0), 1.49*
3042.63	(0), 1.61	2694.20	(0), 1.29
2997.97	(0?), 1.15*	2677.13	(0), 1.71
2989.80	(0), 1.45	2674.54	(0), 1.58
2983.74	(.72), 2.13	2659.44	(.40), 1.20
2959.09	(0), 1.59	2650.84	(0), 1.55
2929.79	(0), 1.64	2646.87	(0), 1.43
2921.40	(0), 1.39	2639.33	(0), 1.27
2919.35	(0), 1.16*	2619.56	(0), 1.29
2913.57	(0, .82), 2.02	2596.00	(0), 1.55
2913.30	(0), 1.11	2505.93	(0), 1.69

* Calculated; see Table II.

cision was reached only because, if they are assigned as given, the whole scheme for the lower level is entirely inverted. This complete inversion is to be expected from comparisons with other similar spectra.

The g-values of the intermediate levels are decidedly irregular and do not allow of determination of the multiplicity and l-values. The values assigned are the writer's estimates from combinations and intensities. Owing to the great separation of levels, no attempt was made to find multiplets with the data on hand. It may be remarked that we here have a case where the jump of l to $l \pm 2$ appears to occur very often and makes it very difficult to determine the levels from combinations.

TABLE II

INTERPRETED ZEEMAN PATTERNS

λ (Air)	Zeeman Pattern
5368.99........	Obs. ($\bar{0}$, .27, .55), 1.73 Calc. ($\bar{0}$, .27, .54), .65, .92, 1.19, 1.46, $\overline{1.73}$ $g\,{}^3\bar{F}_2=.92$; $g3_3=1.19$
5227.66........	Obs. (.36), 1.29 Calc. (.18, $\overline{.36}$), 1.01, $\overline{1.19}$, $\overline{1.37}$, 1.55 $g\,{}^3\bar{P}_2=1.19^*$; $g1_2=1.37^*$
5130.91........	Obs. (0), .50 Calc. (0), .50 $gK_1=.50$; $g14_0=0$
4737.57........	Obs. ($\bar{0}$, .50), $\overline{.50}$, 1.02, 1.52 Calc. ($\bar{0}$, .50), $\overline{.50}$, 1.00, 1.50 $g\,{}^1D_2=1.00$; $g29_1=1.50$
4684.10........	Obs. (0), .86 Calc. ($\bar{0}$, .21), $\overline{.71}$, .92, 1.13 $g\,{}^3\bar{F}_2=.92^*$; $g5_1=1.13^*$
4640.82........	Obs. (0), 1.13 Calc. ($\bar{0}$, .32), .50, .82, $\overline{1.24}$ $g10_2=.82^*$; $gK_1=.50^*$
4577.42........	Obs. (.35), 1.2 Calc. (.21, $\overline{.50}$), .67, $\overline{.92}$, $\overline{1.17}$, 1.42 $g\,{}^3\bar{F}_2=.92^*$; $g6_2=1.17^*$
4554.59........	Obs. (0), 1.35 Calc. ($\bar{0}$, .02), $\overline{1.38}$, 1.40, 1.42 $g\,{}^3\bar{P}_1=1.42^*$; $g12_2=1.40^*$
4481.64........	Obs. (0), 1.42 Calc. (0), 1.42 $g\,{}^3\bar{P}_1=1.42$; $g14_0=0$
4445.56........	Obs. ($\bar{0}$, .88), .45, 1.39, $\overline{2.21}$ Calc. ($\bar{0}$, .88), .50, 1.37, $\overline{2.24}$ $g\,{}^3D_1=.45$; $g1_2=1.33$
4442.52........	Obs. ($\bar{0}$, .33, .68), $\overline{.33}$, .68, 1.04, 1.36, 1.69 Calc. ($\bar{0}$, .34, .68), $\overline{.35}$, .69, 1.03, 1.37, 1.71 $g\,{}^3\bar{F}_3=1.03$; $g1_2=1.37$
4288.08........	Obs. (.23), .90 Calc. (.10, $\overline{.20}$), .72, $\overline{.82}$, $\overline{.92}$, 1.02 $g\,{}^3\bar{F}_2=.92^*$; $g10_2=.82^*$
4281.78........	Obs. (0), 1.21 Calc. ($\bar{0}$, .07), 1.13, 1.20, $\overline{1.27}$ $g\,{}^3\bar{P}_2=1.20^*$; $g5_1=1.13^*$
4192.43........	Obs. (0), 1.16 Calc. (.03, .06), 1.14, $\overline{1.17}$, $\overline{1.20}$, 1.23 $g\,{}^3\bar{P}_2=1.20^*$; $g6_2=1.17^*$
4164.54........	Obs. (.36), .92, 1.41 Calc. (.15, .30, $\overline{.45}$), .74, .89, $\overline{1.04}$, $\overline{1.19}$, 1.34, 1.49 $g\,{}^3\bar{F}_3=1.04^*$; $g3_3=1.19^*$
3996.59........	Obs. (.51, $\overline{.92}$), .42, $\overline{.92}$, $\overline{1.41}$, 1.90 Calc. (.49, $\overline{.98}$), .43, $\overline{.92}$, $\overline{1.41}$, 1.90 $g\,{}^3\bar{F}_2=.92$; $g12_2=1.41$
3948.38........	Obs. (.34, $\overline{.73}$), $\overline{.73}$, $\overline{1.20}$, 1.58 Calc. (.38, $\overline{.76}$), .44, .82, $\overline{1.20}$, 1.58 $g\,{}^3\bar{P}_2=1.20$; $g10_2=.82$
3699.89........	Obs. (.44), $\overline{1.27}$, 1.61 Calc. (.20, $\overline{.40}$), 1.00, $\overline{1.20}$, $\overline{1.40}$, 1.60 $g\,{}^3\bar{P}_2=1.20^*$; $g12_2=1.40^*$
3674.05........	Obs. ($\bar{0}$, .60), 1.15, $\overline{1.76}$ Calc. (0, .58), .59, 1.17, $\overline{1.76}$ $g\,{}^3D_1=.59$; $g6_2=1.17$

TABLE II—*Continued*

λ (Air)	Zeeman Pattern
3672.00........	Obs. (o), 1.00 Calc. (ō, .13, .26), $\overline{.78}$, .91, 1.04, 1.17, 1.30 $g^3\overline{F}_3=1.04$*; $g6_2=1.17$*
3610.91........	Obs. (o), 1.01 Calc. (ō, .48), $\overline{.34}$, .82, 1.50 $g^3\overline{F}_2=.92$*; $g18_1=1.50$*
3587.38........	Obs. (o), 1.49 Calc. (o), 1.50 $g^3\overline{P}_1=1.50$; $g26_0=0$
3485.27........	Obs. (ō, .38), .88, $\overline{1.25}$ Calc. (ō, .38), .49, .87, $\overline{1.25}$ $g^3D_1=.49$; $g10_2=.87$
3483.42........	Obs. (o), 1.43 Calc. (ō, .17, .34), .70, .87, 1.04, 1.21, $\overline{1.38}$ $g^3F_3=1.04$*; $g10_2=.87$*
3290.20........	Obs. (ō, .86), 1.36, $\overline{2.27}$ Calc. (ō, .88), .51, 1.39, $\overline{2.27}$ $g^3D_1=.51$; $g12_2=1.39$
3255.93........	Obs. (o), 1.13 Calc. (o), 1.13 $g^1S_0=0$; $g5_1=1.13$
3251.97........	Obs. (o), .46 Calc. (o), .46 $g^3D_1=.46$; $g14_0=0$
3156.56........	Obs. (.60), 1.10 Calc. (.$\overline{60}$), .50, $\overline{1.10}$ $g^3D_1=.50$; $g16_1=1.10$
3064.69........	Obs. (o), 1.25 Calc. (ō, .02, .04), $\overline{1.30}$, 1.32, 1.33, 1.35, 1.37 $g^3D_3=1.33$*; $g1_2=1.37$*
2997.97........	Obs. (o?), 1.15 Calc. (ō, .19, .38), .81, 1.00, 1.19, 1.38, $\overline{1.57}$ $g^1D_2=1.00$*; $g3_3=1.19$*
2919.38........	Obs. (o), 1.16 Calc. (ō, .30), $\overline{.90}$, 1.20, 1.50 $g^3\overline{P}_2=1.20$*; $g29_1=1.50$
2803.22........	Obs. (o), 1.04 Calc. (o), 1.04 $g^1S_0=0$; $g16_1=1.04$
2698.40........	Obs. (o), 1.49 Calc. (o), 1.49 $g^1S_0=0$; $g18_1=1.49$

* Value assumed as known from other calculations.

Table II contains all those Zeeman patterns which have so far been analyzed. These are designated by a star (*) in Table I.

Table III includes all the levels known at present in the platinum spectrum. The low levels are probably correct in all their details but the assignment of the intermediate set is somewhat doubtful.

Not much can be said about the upper set of levels. Most of the combinations due to these lie in the infra-red. It seems that the level designated as K_1 may be $^3D_1$ ($g=0.5$). With the exception of

TABLE III

TERM ASSIGNMENTS AND *j*-VALUES

Term	ν (Vac.)	Term	ν (Vac.)	Term	ν (Vac.)
$^3D_3$	0	$14_0=P_0$	40873.5	39_2	51752.3
a^1D_2	775.9	$15_3=F_3$	40970.1	$40_{1\text{ or }2}$	52071.6
$^3\bar{F}_4$	823.7	$16_1=P_1$	41802.7		
$^1S_0$	6140.0	$17_3=\bar{D}_3$	42660.2	A_3	52379.3
$^3D_2$	6567.5	$18_1=P_1$ or $\bar{D}_1$	43187.8	B_2	52667.2
$^3\bar{F}_3$	10116.8	$19_3=\bar{D}_3$ or F_3	43945.7		
$^3D_1$	10132.0	$20_4=F_4$	44432.7	41_2	52708.3
$^3\bar{P}_2$	13496.3	$21_2=\bar{D}_2$	44444.4	$42_{1\text{ or }2}$	53019.2
$^3\bar{F}_2$	15501.8	$22_3=F_3$	44730.3	43_2	53955.3
$^3\bar{P}_1$	18566.5	$23_1=P_1$	45398.4	44_3	54839.2
$^1G_4$	21967.1	$24_2=\bar{D}_2$	46170.4	$45_{1\text{ or }2}$	55216.8
b^1D_2	26638.6	$25_2=\bar{D}_2$	46419.9		
		$26_0=P_0$	46433.9	C_5	55640.7
$1_2=\bar{D}_2$	32620.0	$27_3=F_3$	46622.5	D_4	56784.4
$2_5=\bar{G}_5$	33680.5	$28_4=\bar{G}_4$	46965.1	E_3	59751.2
$3_3=F_3$	34122.1	$29_1=P_1$ or $\bar{D}_1$	47740.6	F_3	59764.3
$4_3=\bar{D}_3$ or F_3	35321.7	$30_4=\bar{G}_4$	48353.8	G_1	59782.8
$5_1=\bar{D}_1$	36844.7	$31_2=P_2$	48535.6	H_3	59872.1
$6_2=\bar{D}_2$	37342.1	$32_3=\bar{D}_3$	48779.3	I_4	59882.4
$7_4=F_4$	37590.7	33_3	49286.1	J_2	59908.1
$8_3=\bar{D}_3$	37769.0	34_1	49544.5	$K_1={}^3D_1$	60357.8
$9_5=\bar{G}_5$	38536.2	35_2	49880.8	L_2	60640.6
$10_2=F_2$	38815.9	36_1	50055.3	M_3	60790.4
$11_4=F_4$	40194.2	37_2	51286.9	N_4	60884.0
$12_2=\bar{D}_2$	40516.3	38_2	51545.5	O_4	64505.9
$13_2=\bar{D}_2$	40787.9				

the lower levels, purely arbitrary designations have been given. The *j*-values for all levels are probably correct.

Table IV includes all the real lines computed from the lower and intermediate levels.

TABLE IV

λ (Air)	I	υ (Vac.)	Class.	λ (Air)	I	υ (Vac.)	Class.
8224.79...	6	12155.0	${}^1G_4-3_3$	3953.63...	1	25286.1	${}^3\bar{F}_2-13_2{}^*$
7486.02...	3	13354.6	${}^1G_4-4_3$	3948.38...	4	25319.7	${}^3\bar{P}_2-10_2{}^*$
7113.75...	10	14053.5	${}^3\bar{P}_1-1_2$	3925.34...	4	25468.3	${}^3\bar{F}_2-15_3{}^*$
7065.54...	2	14149.3	$b^1D_2-13_2$	3699.89...	4	27020.2	${}^3\bar{P}_2-12_2{}^*$
6975.71...	2	14331.5	$b^1D_2-15_3$	3681.07...	0	27158.3	${}^3\bar{F}_2-17_3$
6592.65...	2	15164.2	$b^1D_2-16_1$	3674.05...	4	27210.3	${}^3D_1-6_2{}^*$
6398.88...	3	15623.7	${}^1G_4-7_4$	3672.00...	4	27225.4	${}^3\bar{F}_3-6_2{}^*$
6326.58...	10	15801.9	${}^1G_4-8_3$	3663.09...	4	27291.6	${}^3\bar{P}_2-13_2{}^*$
6040.90...	0	16549.2	$b^1D_2-18_1$	3659.38...	2	27319.3	${}^1G_4-33_3$
6033.67...	1	16569.1	${}^1G_4-9_5$	3638.78...	6	27473.9	$\left\{{}^3\bar{P}_2-15_3{}^*\right.$
5840.12...	15	17118.2	${}^3\bar{F}_2-1_2$				$\left.{}^3\bar{F}_3-7_4{}^*\right.$
5525.85...	4	18091.8	$b^1D_2-22_3$	3628.11...	5	27555.5	${}^3D_2-3_3{}^*$
5469.49...	2	18278.2	${}^3\bar{P}_1-5_1$	3621.67...	2	27603.8	${}^3\bar{P}_1-24_2$
5368.99...	15	18620.3	${}^3\bar{F}_2-3_3{}^*$	3615.28...	0	27653.8	${}^3\bar{F}_3-8_3$
5324.59...	2	18775.5	${}^3\bar{P}_1-6_2{}^*$	3610.91...	2	27686.0	${}^3\bar{F}_2-18_1{}^*$
5260.86...	5	19003.0	${}^1G_4-15_3{}^*$	3589.17...	2	27853.7	${}^3\bar{P}_1-25_2$
5227.66...	20	19123.6	${}^3\bar{P}_2-1_2{}^*$	3587.38...	2	27867.6	${}^3\bar{P}_1-26_0{}^*$
5118.44...	2	19531.8	$b^1D_2-24_2{}^*$	3514.69...	4	28443.9	${}^3\bar{F}_2-19_3$
5053.87...	1	19781.3	$b^1D_2-25_2$	3498.19...	1	28578.2	$b^1D_2-45_{1,2}$
5044.04...	10	19819.9	${}^3\bar{F}_2-4_3$	3485.27...	6	28648.0	${}^3D_1-10_2{}^*$
5002.65...	4	19983.9	$b^1D_2-27_3{}^*$	3483.42...	5	28699.2	${}^3\bar{F}_3-10_2{}^*$
4831.23...	2	20692.9	${}^1G_4-17_3{}^*$	3476.76...	2	28754.3	${}^3D_2-4_3$
4737.57...	4	21102.0	$b^1D_2-29_1{}^*$	3454.13...	3	28942.5	${}^3\bar{F}_2-21_2$
4684.10...	5	21342.9	${}^3\bar{F}_2-5^{1*}$	3427.94...	4	29163.7	${}^3\bar{P}_2-17_3{}^*$
4580.52...	3	21825.5	${}^3\bar{P}_2-4_3$	3426.72...	2	29174.1	${}^3\bar{P}_1-29_1$
4577.42...	5	21840.3	${}^3\bar{F}_2-6_2{}^*$	3420.34...	0	29228.5	${}^3\bar{F}_2-22_3$
4565.57...	1	21897.0	$b^1D_2-31_2$	3367.00...	4	29691.5	${}^3\bar{P}_2-18_1$
4554.59...	6	21949.7	${}^3\bar{P}_1-12_2{}^*$	3343.90...	4	29896.6	${}^3\bar{F}_2-23_1{}^*$
4489.35...	1	22268.8	${}^3\bar{F}_2-8_3$	3335.79...	2	29969.3	${}^3\bar{P}_1-31_2$
4481.64...	3	22307.1	${}^3\bar{P}_1-14_0{}^*$	3323.80...	6	30077.4	${}^3\bar{F}_3-11_4{}^*$
4445.56...	4	22488.1	$a^3D_1-1_2{}^*$	3301.85...	8u	30277.4	${}^3D_2-5_1\dagger$
4442.52...	6	22503.5	${}^3\bar{F}_3-1_2{}^*$	3290.20...	6	30384.6	${}^3D_1-12_2{}^*$
4414.28...	2	22647.5	$b^1D_2-33_3{}^*$	3283.20...	2	30449.5	${}^3\bar{P}_2-19_3$
4391.80...	4	22763.4	${}^1G_4-22_3$	3261.08...	2	30655.9	${}^3D_1-13_2{}^*$
4364.46...	4	22906.0	$b^1D_2-34_1{}^*$	3259.72...	4	30668.7	${}^3\bar{F}_2-24_2{}^*$
4288.08...	4	23314.0	${}^3\bar{F}_2-10_2{}^*$	3255.93...	6	30704.4	${}^1S_0-5_1{}^*$
4281.78...	1	23348.2	${}^3\bar{P}_2-5_1{}^*$	3251.97...	5	30741.8	${}^3D_1-14_0{}^*$
4269.25...	2	23416.8	$b^1D_2-36_1{}^*$	3248.48...	2	30774.8	${}^3D_2-6_2$
4192.43...	4	23845.8	${}^3\bar{P}_2-6_2{}^*$	3240.20...	5	30853.4	${}^3\bar{F}_3-15_3{}^*$
4164.54...	4	24005.6	${}^3\bar{F}_3-3_3{}^*$	3233.44...	5	30918.4	${}^3\bar{F}_2-25_2{}^*$
4118.69...	5	24272.9	${}^3\bar{P}_2-8_3{}^*$	3230.29...	5	30948.1	${}^3\bar{P}_2-21_2{}^*$
4054.78...	2	24655.3	${}^1G_4-27_3{}^*$	3227.16...	2	30978.1	${}^3\bar{P}_1-34_1$
3996.59...	3	25014.2	${}^3\bar{F}_2-12_2{}^*$	3212.36...	2	31120.8	${}^3\bar{F}_2-27_3$
3966.35...	3	25205.0	${}^3\bar{F}_3-4_3{}^*$	3204.06...	6	31201.4	${}^3D_2-8_3{}^*\dagger$

TABLE IV—*Continued*

λ (Air)	I	ν (Vac.)	Class.	λ (Air)	I	ν (Vac.)	Class.
3200.69...	4	31234.3	$^3\bar{P}_2-22_3$*	2825.07...	1	35386.9	$^3\bar{P}_1-43_2$
3192.48...	3	31314.6	$^3\bar{P}_1-35_2$	2803.22...	6	35662.8	$^1S_0-16_1$*†
3174.84...	2	31488.6	$^3\bar{P}_1-36_1$	2793.63...	2	35785.2	$^3\bar{F}_2-37_2$
3156.56...	5	31671.0	$^3D_1-16_1$*	2793.28...	4	35789.7	$^3\bar{P}_2-33_3$*
3139.34...	7	31844.6	$a^1D_2-1_2$†	2773.99...	4	36038.5	$^3D_1-24_2$*
3133.64...	1	31902.4	$^3P_2-23_1$	2773.64...	2	36043.1	$^3\bar{F}_2-38_2$
3100.96...	4	32238.8	$^3F_2-29_1$	2773.28...	4	36047.8	$^3\bar{P}_2-34_1$*
3100.02...	4	32248.5	$^3D_2-10_2$	2772.84...	2	36053.5	$^3\bar{F}_3-24_2$
3071.94...	5	32543.3	$^3\bar{F}_3-17_3$	2771.65...	4R	36069.0	$a^1D_2-5_1$*†
3064.69...	6R	32620.3	$^3D_3-1_2$*†	2769.84...	4	36092.5	$^3D_2-17_3$
3059.63...	4	32674.2	$^3\bar{P}_2-24_2$	2757.69...	2	36251.6	$^3\bar{F}_2-39_2$
3055.28...	4	32720.7	$^3\bar{P}_1-37_2$	2754.90...	5	36288.3	$^3D_1-25_2$*†
3042.63...	4R	32856.8	$^3\bar{F}_4-2_5$*†	2753.85...	4	36302.1	$^3D_1-26_0$
3041.21...	2	32872.1	$^1G_4-44_4$	2753.74...	2	36303.1	$^3\bar{F}_3-25_2$
3036.43...	6	32923.9	$^3\bar{P}_2-25_2$	2747.59...	4	36384.8	$^3\bar{P}_2-35_2$*
3026.32...	2	33033.8	$^3\bar{F}_2-31_2$	2738.45...	4	36506.2	$^3\bar{F}_3-27_3$*
3024.28...	2	33056.1	$^3D_1-18_1$	2734.47...	2	36559.4	$^3\bar{P}_2-36_1$
3017.87...	4	33126.3	$^3\bar{P}_2-27_3$	2733.96...	8R	36566.2	$a^1D_2-6_2$*†
3012.37...	2	33186.8	$^3\bar{P}_1-39_2$	2733.67...	5R	36570.1	$^3\bar{F}_2-40_{1,2}$†
3004.15...	2	33277.6	$^3\bar{F}_2-32_3$	2729.90...	5	36620.6	$^3D_2-18_1$†
3002.26...	4	33298.6	$^3\bar{F}_4-3_3$†	2719.02...	6R	36767.1	$^3\bar{F}_4-7_4$*†
2997.97...	7R	33346.2	$a^1D_2-3_3$*†	2713.09...	4	36847.2	$^3\bar{F}_3-28_4$*
2983.74...	2	33505.3	$^3\bar{P}_1-40_{1,2}$*	2705.88...	5R	36947.0	$^3\bar{F}_4-8_3$*†
2959.09...	4	33784.3	$^3\bar{F}_2-33_3$*	2702.38...	6R	36993.5	$a^1D_2-8_3$†
2944.77...	3	33948.6	$^3D_2-12_2$	2698.40...	6	37048.0	$^1S_0-18_1$*†
2929.79...	8R	34122.3	$^3D_3-3_3$*†	2686.89...	0	37206.5	$^3\bar{F}_2-41_2$
2928.09...	4	34142.0	$^3\bar{P}_1-41_2$	2677.13...	5R	37342.4	$^3D_3-6_2$*†
2921.40...	3	34220.2	$^3D_2-13_2$*	2674.54...	4	37378.5	$^3D_2-19_3$*
2919.35...	4	34244.2	$^3\bar{P}_2-29_1$*	2664.63...	2	37517.4	$^3\bar{F}_2-42_{1,2}$
2913.57...	4	34312.1	$^3D_1-21_2$*	2659.44...	10R	37590.7	$^3D_3-7_4$*†
2913.27...	2	34315.7	$^3F_3-20_4$	2658.16...	4	37608.8	$^3D_1-29_1$
2912.30...	8	34327.1	$^3\bar{F}_3-21_2$*	2650.84...	4R	37712.7	$^3\bar{F}_4-9_5$*†
2907.89...	4	34379.1	$^3\bar{F}_2-35_2$	2646.87...	6R	37769.2	$^3D_3-8_3$*†
2905.90...	4	34402.7	$^3D_2-15_3$*	2645.35...	4	37790.9	$^3\bar{P}_2-37_2$
2901.68...	0	34452.7	$^3\bar{P}_1-42_{1,2}$	2639.33...	5	37877.1	$^3D_2-21_2$*†
2897.89...	5	34497.8	$^3\bar{F}_4-4_3$*†	2628.02...	7R	38040.1	$a^1D_2-10_2$†
2893.87...	6	34545.7	$a^1D_2-4_3$*†	2627.37...	4	38049.5	$^3\bar{P}_2-38_2$
2893.26...	4	34554.0	$^3\bar{F}_2-36_1$*	2619.56...	4	38162.9	$^3D_2-22_3$*
2888.20...	4	34613.5	$^3\bar{F}_3-22_3$*	2613.10...	0	38256.6	$^3\bar{P}_2-41_2$
2853.07...	4	35039.7	$^3\bar{P}_2-31_2$	2603.13...	4	38403.8	$^3D_1-31_2$
2837.23...	2	35235.3	$^3D_2-16_1$	2602.07...	0	38419.5	$^3\bar{F}_3-31_2$
2834.71...	4	35266.6	$^3D_1-23_1$	2599.90...	2	38451.5	$^3\bar{F}_2-43_2$
2833.38...	1	35283.2	$^3\bar{P}_2-32_3$	2574.48...	2	38831.2	$^3D_2-23_1$
2830.29...	8R	35321.7	$^3D_3-4_3$*†	2552.23...	3	39169.7	$^3\bar{F}_3-33_3$

TABLE IV—*Continued*

λ (Air)	I	ν (Vac.)	Class.	λ (Air)	I	ν (Vac.)	Class.
2549.46...	3	39212.2	$^3\bar{P}_2-41_2$	2326.11...	2	42977.0	$^3D_2-34_1$†
2546.46...	0	39258.6	$^1S_0-23_1$	2318.29...	2	43122.0	$^3\bar{F}_4-19_3$†
2541.35...	2	39337.4	$^3\bar{F}_2-44_3$	2315.50...	2	43173.9	$a^1D_2-19_3$†
2539.20...	3	39370.7	$^3\bar{F}_4-11_4$†	2308.04...	3	43313.4	$^3D_2-35_2$†
2536.47...	4?	39412.1	$^3D_1-33_1$	2303.18...	3	43404.8	$^1S_0-34_1$†
2529.40...	2	39525.2	$^3\bar{P}_2-42_{1,\,2}$	2298.78...	1	43487.8	$^3D_2-36_1$†
2524.31...	3	39602.9	$^3D_2-24_2$†	2292.38...	2	43609.3	$^3\bar{F}_4-20_4$†
2517.16...	1	39715.4	$^3\bar{F}_2-45_{1,\,2}$	2289.27...	2	43668.6	$a^1D_2-21_2$†
2515.58...	3	39740.3	$a^1D_2-12_2$†	2280.53...	1	43835.9	$^3\bar{F}_3-43_2$
2515.03...	3	39748.9	$^3D_1-35_2$	2276.86...	1	43906.5	$^3\bar{F}_4-22_3$†
2514.07...	2	39764.2	$^3\bar{F}_3-35_2$	2276.42...	1	43915.0	$^1S_0-36_1$†
2508.50...	3	39852.4	$^3D_2-25_2$†	2274.83...	1	43945.7	$^3D_3-19_3$†
2504.05...	2	39923.3	$^3D_1-36_1$	2274.38...	2	43954.4	$a^1D_2-22_3$†
2498.50...	4	40012.0	$a^1D_2-13_2$†	2249.90...	1	44432.6	$^3D_3-20_4$†
2495.82...	4	40054.9	$^3D_2-27_3$†	2249.29...	1	44444.7	$^3D_3-21_2$†
2490.13...	2	40146.4	$^3\bar{F}_4-15_3$†	2245.51...	2	44519.5	$a^1D_2-23_1$†
2487.15...	4R	40194.5	$^3D_3-11_4$†	2234.91...	1	44730.6	$^3D_3-22_3$†
			$a^1D_2-15_3$†	2222.64...	1	44977.5	$^3D_2-38_2$†
2471.01...	3	40457.1	$^3\bar{P}_2-43_2$	2217.33...	1	45085.2	$^3D_1-45_{1,\,2}$†
2467.42...	6R	40515.9	$^3D_3-12_2$†	2202.20...	15‡	45394.9	$a^1D_2-24_2$†
2450.97...	3	40787.8	$^3D_3-13_2$†	2196.88...	1	45504.8	$^3D_2-40_{1,\,2}$
2440.08...	4R	40969.8	$^3D_3-15_3$†	2190.12...	8‡	45645.3	$a^1D_2-25_2$†
2436.69...	4R	41026.8	$a^1D_2-16_1$†	2182.73...	10‡	45799.8	$^3\bar{F}_4-27_3$†
2429.08...	2	41155.2	$^3D_1-37_2$	2180.46...	15‡	45847.5	$a^1D_2-27_3$†
2428.19...	2R?	41170.4	$^3\bar{F}_3-37_2$	2166.58...	1u	46141.2	$^3D_2-41_2$†
2428.03...	3	41173.1	$^3D_2-29_1$†				$^3\bar{F}_4-28_4$†
2418.05...	3	[illegible]1343.1	$^3\bar{P}_2-44_3$†	2165.14...	30‡	46171.8	$^3D_3-24_2$†
2413.07...	1	41428.4	$^3\bar{F}_3-38_5$	2153.50...	20‡	46421.4	$^3D_3-25_2$†
2403.10...	4R	41600.2	$^1S_0-29_1$†	2152.03...	10‡	46453.1	$^3D_2-42_{1,\,2}$†
2401.88...	3	41620.7	$^3D_1-39_2$†	2144.18...	50‡	46623.1	$^3D_3-27_3$†
2401.01...	1	41636.5	$^3\bar{F}_3-39_2$	2128.55...	15‡	46965.4	$a^1D_2-29_1$†
2396.17...	2	41720.6	$^3\bar{P}_2-45_{1,\,2}$				$^3D_3-28_4$†
2389.54...	3	41836.3	$^3\bar{F}_4-17_3$†	2103.25...	10‡	47530.1	$^3\bar{F}_4-30_4$†
2386.83...	2?	41883.8	$a^1D_2-17_3$	2084.50...	12‡	47957.8	$^3\bar{F}_4-32_3$†
2383.65...	4	41939.7	$^3D_1-40_{1,\,2}$†	2082.41...	9‡	48005.9	$a^1D_2-32_3$†
2368.28...	4R	42211.8	$^3D_2-33_3$†	2070.84...	10‡	48274.1	$^3D_2-44_3$†
2357.09...	4R	42412.2	$a^1D_2-18_1$†	2067.40...	10‡	48354.4	$^3D_3-30_4$†
2347.16...	0	42519.6	$^3\bar{F}_3-41_2$	2062.69...	8‡	48464.8	$^3\bar{F}_4-33_3$†
2343.39...	2	42660.1	$^3D_3-17_3$	2060.66...	4‡	48512.6	$a^1D_2-33_3$†
2340.18...	2	42718.6	$^3D_2-33_3$†	2059.57...	6‡	48538.2	$^3D_3-31_2$†
2330.97...	1	42887.4	$^3D_1-42_{1,\,2}$	2049.30...	4‡	48781.4	$^3D_3-32_3$†

* Zeeman effect.

† Absorption (Meggers and Laporte, *Physical Review*, 28, 642, 1926).

‡ Wave-length and intensity from Meggers and Laporte.

TABLE V

λ (Air)	I	ν (Vac.)	Class.
8762.48...	0	11409.2	15_3-A_3
8301.87...	1	12042.2	29_1-G_1
8259.03...	1	12104.6	32_3-N_4 31_2-L_2
8227.52...	2	12151.0	12_2-B_2
8204.45...	3	12185.2	11_4-A_3
8093.88...	1	12351.7	20_4-D_4
7786.78...	3	12838.7	19_3-D_4
7749.74...	2	12900.1	29_1-L_2
7614.90...	1	13128.5	27_3-E_3
7607.23...	1	13141.8	27_3-F_3
7217.58...	6	13851.3	10_2-B_2
7179.94...	0	13923.9	26_0-K_1
7131.64...	2	14018.2	27_3-L_2
7078.08...	3	14124.2	17_3-D_4
7056.27...	1	14167.9	27_3-M_3
7030.09...	2	14220.7	25_2-L_2
6956.87...	0	14370.3	25_2-M_3
6908.80...	2	14470.3	24_2-L_2
6842.60...	8	14610.3	8_3-A_3
6838.08...	3	14619.9	24_2-M_3
6760.00...	20	14788.8	7_4-A_3
6710.39...	10	14898.2	8_3-B_2
6655.54...	1	15020.9	22_3-E_3
6648.31...	6	15037.3	6_2-A_3
6602.34...	1	15142.0	22_3-H_3
6597.93...	2	15152.1	22_3-I_4
6523.44...	15	15325.1	6_2-B_2
6472.25...	0	15446.3	11_4-C_5
6321.66...	1	15814.3	15_3-D_4
6318.36...	7	15822.5	5_1-B_2
6283.48...	5	15910.4	22_3-L_2
6282.25...	2	15913.5	21_2-K_1
6273.04...	1	15936.8	19_3-I_4
6188.77...	0	16153.8	22_3-N_4 30_4-O_4
6172.56...	4	16196.3	21_2-L_2
6111.62...	1	16357.8	20_4-M_3
6076.87...	4	16451.3	20_4-N_4
6026.03...	7	16590.1	12_4-D_4
6024.24...	4	16595.0	18_1-G_1
5979.11...	3	16720.3	18_1-J_2
5860.82...	5	17057.7	4_3-A_3
5844.82...	10	17104.4	9_5-C_5 17_3-F_3
5822.52...	1	17169.9	18_1-K_1
5763.59...	6	17345.5	4_3-B_2
5728.14...	1	17452.8	18_1-L_2
5698.98...	3	17542.1	28_4-O_4
5560.12...	1	17980.2	16_1-G_1
5560.02...	2	17980.6	17_3-L_2
5521.69...	2	18105.4	16_1-J_2
5514.10...	4	18130.3	17_3-M_3
5485.75...	1	18224.0	17_3-N_4

λ (Air)	I	ν (Vac.)	Class.
5478.50...	12	18248.1	$9_5-D_4^*$
5475.78...	15	18257.2	$3_3-A_3^*$
5390.80...	10	18545.0	$3_3-B_2^*$
5387.88...	4	18555.0	$16_1-K_1^*$
5323.04...	1	18781.1	15_3-E_3
5319.34...	3	18794.1	$15_3-F_3^*$
5288.99...	1	18902.0	15_3-H_3
5286.12...	3	18912.2	15_3-I_4
5268.24...	1	18976.4	13_2-F_3
5257.48...	3	19015.3	$8_3-D_4^*$
5238.47...	1	19084.2	13_2-H_3
5208.59...	2	19193.7	7_4-D_4
5193.91...	3	19248.0	$12_2-F_3^*$
5188.88...	0	19266.6	12_2-G_1
5164.97...	1	19355.6	12_2-H_3
5155.38...	2	19391.6	12_2-J_2
5130.91...	2	19484.3	$14_0-K_1^*$
5108.45...	2	19570.0	$13_2-K_1^*$ $11_4-F_3^*$
5082.35...	2	19670.5	$15_3-L_2^*$
5077.80...	2	19688.1	11_4-I_4
5059.50...	15	19759.3	$1_2-A_3^*$
5055.36...	1	19775.5	22_3-O_4
5044.04...	10	19819.9	15_3-M_3
5038.54...	2	19841.5	12_2-K_1
4997.98...	4	20002.5	$13_2-M_3^*$
4986.86...	3	20047.1	1_2-B_2
4980.40...	3	20073.1	20_4-O_4
4862.40...	2	20560.2	$19_3-O_4^*$
4853.93...	5	20596.1	$11_4-M_3^*$
4831.97...	2	20689.7	$11_4-N_4^*$
4772.32...	3	20948.3	$10_2-F_3^*$
4768.12...	2	20966.8	$10_2-G_1^*$
4747.88...	3	21056.2	10_2-H_2
4739.76...	3	21092.2	$10_2-J_2^*$
4683.38...	0	21346.2	9_5-I_4
4657.95...	9	21462.7	$4_3-D_4^*$
4640.82...	5	21541.9	$10_2-K_1^*$
4580.66...	3	21824.8	10_2-L_2
4576.28...	1	21846.0	17_3-O_4
4552.42...	12	21960.2	$2_5-C_5^*$
4547.88...	8	21982.1	8_3-E_3
4523.00...	10	22103.0	$8_3-H_3^*$
4520.91...	15	22113.3	$8_3-I_4^*$
4515.66...	2	22139.0	$8_3-J_2^*$
4511.24...	6	22160.7	$7_4-E_3^*$
4508.59...	2	22173.7	7_4-R_3
4484.72...	5u	22291.8	$7_4-I_4^*$
4473.45...	3u	22347.9	$9_5-N_4^*$
4458.65...	3	22422.2	$6_2-F_3^*$
4455.00...	2	22440.5	6_2-G_1
4437.31...	4u	22529.9	$6_2-H_3^*$
4430.24...	3	22565.9	$6_2-J_2^*$
4411.43...	3	22662.1	$3_3-D_4^*$

TABLE V—*Continued*

λ (Air)	I	υ (Vac.)	Class.	λ (Air)	I	υ (Vac.)	Class.
4358.36...	2u	22938.0	5_1-G_1*	4092.34...	3	24429.0	4_3-E_3
4343.70...	0	23015.5	6_2-K_1*	3925.34...	4	25468.3	4_3-M_3*
4334.70...	2	23063.2	5_1-J_2*	3910.90...	3	25562.3	4_3-N_4*
4327.07...	4	23103.9	2_5-D_4	3900.72...	4	25629.1	3_3-E_3
4309.18...	1	23199.8	7_4-M_3*	3898.74...	4	25642.1	3_3-F_3*
4290.97...	2	23298.3	6_2-L_2*	3683.02...	4	27144.0	1_2-F_3*
4263.53...	2	23448.3	6_2-M_3*	3674.95...	1	27203.5	2_5-N_4
4247.69...	1	23535.7	15_3-O_4	3668.39...	1	27252.2	1_2-H_3*
4201.14...	2	23796.5	5_1-L_2*	3243.10...	0	30825.8	2_5-O_4

* Zeeman effect.

Table V gives the lines found by combining the upper and intermediate levels. No lines were found for any combinations of the lower and upper levels.

According to Hund's theory, the following are the most probable electronic configurations and levels for platinum: d^8s^2; $^3\overline{F}$, $^3\overline{P}$, ^1G, ^1D, ^1S: d^9s; ^3D, ^1D: d^{10}; ^1S. If the present assignment is correct, all the levels are present with the exception of one of the ^1S-levels and $^3\overline{P}_0$. It is impossible to distinguish ^1S from $^3\overline{P}_0$ from the *g*-values and combinations, and the designation ^1S was arrived at mainly because this would cause the levels to be inverted and from the fact that the first terms in the electronic configurations should be outstanding. It is found that the ***grundterm*** of platinum is ^3D, d^9s, and if this analysis is correct, Meggers' and Laporte's assignment of terms is valid.

The upper levels are probably similar to the lower ones with the s-electron in an excited state. The intermediate levels evidently arise from a configuration where one of the electrons is replaced by a p-electron. This would give rise to terms of the sort $^3(S, P, D, \ldots.)$ and $^1(S, P, D, \ldots.)$.

In conclusion the writer wishes to express his appreciation to Dean Henry G. Gale who suggested this problem and under whose direction this work was carried out, to Dr. F. C. Hoyt for his ready assistance in the interpretation of the results, and to Drs. G. S. Monk and W. W. Watson for invaluable aid in the performance of the experimental work.

RYERSON PHYSICAL LABORATORY
UNIVERSITY OF CHICAGO
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THE ARC AND SPARK SPECTRA OF TITANIUM[1]

PART II. THE ARC SPECTRUM, *Ti* I

By HENRY NORRIS RUSSELL[2]

ABSTRACT

The *arc spectrum of titanium* is complicated. The identified terms include 43 singlets, 65 triplets, and 34 quintets. Combinations between these give 422 multiplets and account for 1394 lines. There are many intercombinations between singlets and triplets, and between triplets and quintets, but none between singlets and quintets.

The *lowest term* is a $^3F'$; next come a $^5F'$ and a ^1D.

Tables of these terms and of the classified lines similar to those in Part I are given, and the *methods* employed in the analysis are illustrated.

The *temperature classification* of the lines is again in agreement with their levels of origin, and the *Zeeman effect* accords with Landé's theory, except for a few terms with abnormal g values. *Tables* are given for more than 300 lines.

Hund's theory accounts for the observed terms in a completely satisfactory manner. The *electron configurations* corresponding to most of them can be assigned with certainty, and for the rest, with little ambiguity.

Seventeen *series* have been identified which converge to seven different limits, all terms of *Ti* II.

The *ionization potential* is 6.81 *volts*.

Comparison of the spectra of *Ti* I and *V* II shows the similarity of their structure, and indicates that the ionization potential of *V* II is approximately 14.1 volts.

I. INTRODUCTION

The present paper completes the investigation of the spectrum of titanium and deals with its most complicated portion—the spectrum of the neutral atom. A considerable part of this has been analyzed by Dr. and Mrs. Kiess,[3] who classified more than 350 lines, including most of the strongest. They proved the existence of triplet and quintet systems, and suspected that of singlets as well. The lowest term is a $^3F'$, the next $^5F'$, followed by a ^1D, a $^3P'$, and a second $^3F'$. About fifty multiplets were identified, resulting from combinations of the low triplet terms with higher ones of types S', P, D', F, and G'; quintet D', F, and G' terms combining with the low $^5F'$ term were found, and intercombinations between the triplets and quintets. A $^5P'$ term, combining with $^5S'$, ^5P, and $^5D'$ terms, was also found, but was not connected with the rest of the scheme.

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[2] Research associate of the Mount Wilson Observatory, Carnegie Institution of Washington.

[3] *Journal of the Optical Society of America*, **8**, 607, 1924.

The present investigation (which, as has previously been stated, was begun without the knowledge that Dr. and Mrs. Kiess were working on the spectrum) has confirmed their results in almost every detail. The low terms which they found are the most important in the spectrum, and almost all their higher terms have been verified. Both the triplet and quintet systems have, however, been much extended in the course of the present work, and the system of singlets has been worked out in detail. The terms now identified number 43 singlets, 65 triplets, and 34 quintets, or 142 in all, while the number of component levels, or separate energy states in which the neutral titanium atom can exist, which have actually been detected is 364. The combinations between these terms give rise to 422 multiplets and account in all for 1394 lines. Numerous intercombinations occur between the singlets and triplets and between the triplets and quintets, but none have been found between the singlets and quintets.

2. METHODS OF ANALYSIS

The analysis of so complicated a spectrum is not always easy, and some account of the methods employed may be of interest. A complete list of lines attributed to *Ti* I was prepared, and the wave numbers plotted on strips of co-ordinate paper, by means of lines drawn both above and below a longitudinal axis to a distance indicating the strength of the spectral line. The strips were then cut apart along their axes. By shifting one part past the other, after the fashion of a vernier, the search for pairs of lines with identical frequency differences was greatly facilitated. Strips 50 cm long on a scale of two frequency units per millimeter were found convenient. With their aid it is just as easy to "comb" the spectrum for a large known difference of several thousand units as for a small one, the lower half of one strip being set against the upper half of another at the appropriate shift. The temperature classes of the lines were indicated on the strips and all identifications were marked on them as fast as they were made. This method is particularly well adapted to the discovery of skew-symmetrical multiplets, and most of the important terms were found in this way. The isolated group of lines of class I near λ 5200, for example, led to the recognition of the lowest term (later known as a^3F'). Upon combing the spectrum with its

frequency differences, 216 and 170, more than a dozen multiplets were found, each fixing a higher term, and, searching next with the characteristic interval separations of the strongest of these higher terms, the low terms b^3F' and a^3P' were found. Up to this point the L values for the various terms were unknown, but new combinations of the last-mentioned term were clearly PP′ and PS groups, and the nature of the other terms followed.

The $^5F'$ and $^5P'$ terms were found in a similar fashion, aided in the second case by the Zeeman patterns, which are widely resolved. These two terms afford an excellent illustration of the separation of a given system into subsystems, each composed of terms having the same limit in the spark. The higher terms which combine strongly with the $^5P'$ terms combine very weakly with the $^5F'$, and vice versa. In such a case the multiplets resulting from combinations between the two subsystems may be so faint that only the strong "diagonal" lines are observable, and no satellites are available to exhibit the characteristic separations. The diagonal lines themselves, however, may be identified by their own separations, which are the differences of the separations of the components of the terms involved. For example, the low $^5F'$ term and the $^5D'$ term, which combines most strongly with the $^5P'$, have the separations

$^5F'$............	100.21	81.79	62.17	41.97
$^5D'$............	104.56	75.81	49.38	24.36
Diff...........	−4.35	+ 5.98	+12.79	+17.61

Since the terms are "regular," i.e., the component of greatest inner-quantum number is at the highest level, the differences in wave number of the diagonal lines in the resulting multiplet will have the signs and values given above. By plotting five lines with these relative separations on a bit of paper and running this along one of the sets of strips mentioned above, it was very easy to find the following group of lines:

Intensity..	4 III		3 III A		2 III A		1 III A		tr III A
ν.........	28914.47		910.12		916.14		928.94		946.53
$\Delta\nu$.......		−4.35		+6.02		+12.80		+17.59	

which must evidently be the desired combination. In this particular case, some of the satellites have been observed, and the group could

have been found by their aid; but in many other cases the method here suggested is the only available one.

This method is useful only for finding the connections between groups of terms which are already known. For the detection of new terms a similar method, which has proved very useful, may be illustrated by the search for a high $^3F'$ term. If such a term exists, it may be expected to combine with the lowest of the "middle terms" which themselves combine with the low $^3F'$ term. The term values for these terms, as already found from their combinations, are:

		Difference			Difference		
$a^3D'_3$...	20126.13	552.17	a^3F_4....	19573.96	2165.73	$a^3G'_5$...	21739.69
$a^3D'_2$...	20006.08	584.48	a^3F_3....	19421.60	2166.86	$a^3G'_4$....	21588.46
$a^3D'_1$...	19937.88	614.90	a^3F_2....	19322.98	2146.55	$a^3G'_3$...	21469.53

The leading component $^3F'_4$ of the suspected term should combine with the leading components of these three terms, giving lines which should be the strongest in their different multiplets and should have the frequency differences indicated above. The other components, $^3F'_3$ and $^3F'_2$, should each give three lines near the first three and related by the corresponding frequency differences. A search for these differences reveals the lines

	Difference		Difference	
17698.51 (5 IV)	552.28	18250.79 (8 III)	2165.75	16085.04 (20 III)
17653.88 (4 III)	584.42	18238.30 (6 III)	2166.73	16071.57 (12 III)
17600.92 (2 III)	614.81	18215.73 (5 III)	2146.67	16069.06 (8 III)

A single coincidence of a frequency difference with a predicted value may well be a matter of chance—and a number of remarkable instances of this sort have appeared in the present work, sometimes leading it astray; but such coincidences as these, confirmed by the relative intensities and temperature classes of the lines, are all conclusive evidence of the new term (which is called c^3F' in Table I). By the application of these methods many additional terms of the triplet and quintet systems were found. Many faint lines, especially intercombinations, were found in the predicted places upon photographs of the spectrum prepared by Mr. King and Mr. Ellerman, and some, as faint solar lines greatly intensified, in the sun-spot spectrum, which were confirmed later on the laboratory plates.

Measures of these have added about 165 lines to the list of those known to belong to *Ti* I.

When all this had been done, a great many strong lines, some of them of classes I and II, remained outside the scheme, and both the isolation and the Zeeman effect of these lines confirmed Dr. and Mrs. Kiess's suspicion of the existence of a system of singlets, and showed that it must be extensive. The analysis of a singlet system is much more difficult than any other, for neither satellite separations nor Zeeman effects are available. Realizing this, the consideration of the subject was deferred until near the end of the work. By this time a considerable number of pairs of lines had been identified, which by their separations and temperature classes indicated that they were probably due to transitions from known terms of the triplet system to unclassified levels, which might well belong to the singlet system.

The outstanding lines were then examined for constant frequency differences, and two pairs of strong lines were found almost at once, with frequency differences of 1299.93 and 1299.92, which were separated by 6169.16 units. Many other pairs with separation 6169 were then found, showing that this must be the separation of two important low terms, while that of 1299 belongs to higher terms. Moreover, a separation of 1299.93 was found between two other lines, one of which belonged to a pair already identified as a combination with a low $^3H'$ term. The energy level for this term, and later for all the new singlet terms, could then be computed, and many other intercombinations with the triplets were found. Search among the remaining single lines, with the aid of the frequency differences of the higher singlet terms, resulted in the discovery of the lowest level in the singlet system and the classification of a number of conspicuous low-temperature lines arising from this level. More than twenty intercombinations with the triplet system were found, which definitely fixed the inner-quantum number j of this lowest level as 2. It is therefore recorded as a^1D.

The two low terms first mentioned combine with substantially the same higher terms, so that they must be of the same type. Their intercombinations with the triplets show that their j is either 4 or 5, and the fact that they combine with a number of terms which also

combine with a^1D settles that $j=4$, and that the terms are G, a^1G, and b^1G. The higher terms just mentioned must be ^1F terms; the others which combine with the G's must be G′ or H terms. Another low term, which combines with these and not with the ^1F terms, is clearly of type $^1H'$. A number of high terms combining with a^1D but not with the G terms were identified by means of their intercombinations with the low triplet terms, those which combined with a^3F' being evidently $^1D'$ terms, and the rest, which combined with a^3P' only, being recorded as ^1P. This assignment was later confirmed by the discovery of low $^1P'$ and ^1S terms. A number of still higher terms were also identified by combinations with those of the middle levels. The only strong outstanding line, λ 5120, was finally identified as $a^1H'-a^1I'$ by means of a very faint intercombination $a^3H'_5-a^1I'$, which was found in just the predicted place on King's photographs. The discrimination between the ^1H and $^1G'$ terms which combine with the low ^1G and $^1H'$ terms was difficult. The terms a^1G', d^1G' were identified by combinations with a^3F'; and b^1G', c^1G', a^1H, b^1H by the Zeeman patterns of their combinations with $a^3H'_4$, which showed that, for the first two, j was 4, while for the others it was not. Of the remaining terms e^1G', f^1G' combine with a^1F'. The identification of a^1F' itself is not free from ambiguity; so far as the observed combinations go, it might be a G term; and the fact that an F′ term fits much better into Hund's theoretical scheme has largely influenced this assignment.

All told, even terms of types S, P′, D, F′, G, and H′ and odd terms S′, P, D′, F, G′, H, and I′ have been found in the singlet system. A few outstanding, rather weak, isolated lines may be singlets, belonging here or in other places where they could be identified only by intercombinations much fainter than themselves.

3. TABLES OF TERMS AND LINES

A complete list of the terms which have been identified and those with which each term combines is given in Table I. The energy levels are counted upward from the normal state $a^3F'_2$. The largest number of them of any sort is 13 for $^3D'$; half of the alphabet is used up merely in labeling these terms for identification. The lowest

term, a^3F', gives observable combinations with no less than 52 others; a^3P' combines with 41, and a^1D with 38.

Almost all the terms are regular, only three being wholly or partially inverted. Landé's interval rules are roughly obeyed, but there are noteworthy exceptions, such as c^3P', a^3H', c^3P, e^5D, and c^5D'.

It may be remarked that $c^3S'_1$ and $i^3D'_3$ have the same value. The combinations, especially with a^3P' and b^3P', show that there are really two different lines here, which are accidentally coincident. As in Part I, the numbers assigned to the multiplets in Table II are given below the combinations in Table I.

TABLE I

Ti I TERMS AND COMBINATIONS

Type	Term	Combinations
aS_0...	15166.59	bP 127, cP 222, dP 228, eP 295
aP'_1...	20062.98	aS' 89, aP 24, bP 44, cP 111, dP 115, eP 197, cD' 45, dD' 217, eD' 219
bP'_1...	53663.32	aS' 49, bP 101, cP 41
aD_2...	7255.29	aP 269, bP 291, cP 361, dP 365, eP 395, aD' 43, bD' 143, cD' 296, dD' 398, eD' 401, aF 46, bF 255, cF 336, dF 373, eF 387, fF 414, a^3S' 83, c^3P 256, d^3P 327, e^3P 374, f^3P 388, g^3P 406, b^3D' 95, c^3D' 134, d^3D' 193, e^3D' 225, f^3D' 340, g^3D' 351, h^3D' 370, i^3D' 378, j^3D' 389, k^3D' 390, e^3F 275, f^3F 338, h^3F 385, d^3G' 229, e^3G' 334, f^3G' 383
bD_2...	20209.64	cP 104, dP 114, eP 195, eD' 216, bF 18, cF 79, dF 133, eF 161
cD_2...	44581.16	aD' 186, bD' 71, aF 179
dD_2...	50128.08	aP 64, aD' 299, aF 293
aF'_3...	29818.31	eF 8, fF 99, eG' 31, fG' 63
bF'_3...	41087.31	aD' 110, aF 100, aG' 61, a^3F 165
cF'_3...	46650.26	aD' 235, aF 230, aG' 173
aG_4...	12118.46	bF 146, cF 252, dF 300, eF 317, fF 396, aG' 17, bG' 221, cG' 277, eG' 354, fG' 384, aH 189, bH 308, cH 366, e^3F 177, d^3G' 121, c^3H 282
bG_4...	18287.62	bF 40, cF 118, dF 174, fF 332, bG' 84, cG' 144, dG' 191, eG' 248, fG' 298, aH 62, bH 196, f^3G' 199, b^3H 76, c^3H 151
cG_4...	46068.04	aF 218, aG' 160
dG_4...	52125.98	aF 325, aG' 286, bG' 57
aH'_5...	20795.65	bG' 47, cG' 90, dG' 132, eG' 198, fG' 251, aH 32, bH 137, cH 215, aI' 122
bH'_5...	45485.35	aG' 150
aS'_0...	38200.94	aP' 89, bP' 49
aP_1...	33660.73	aP' 24, aD 269, dD 64, a^3P' 245
bP_1...	34947.02	aS 127, aP' 44, bP' 101, aD 291, a^3P' 266
cP_1...	39078.00	aS 222, aP' 111, bP' 41, aD 361, bD 104, a^3P' 337
dP_1...	39265.80	aS 228, aP' 115, aD 365, bD 114, a^3P' 342
eP_1...	42927.55	aS 295, aP' 197, aD 395, bD 195, a^3P' 386
aD'_2...	22081.15	aD 43, cD 186, dD 299, bF' 110, cF' 235, a^3F' 169
bD'_2...	27906.91	aD 143, cD 71, a^3P' 117, a^3F' 294

TABLE I—*Continued*

Type	Term	Combinations				
cD'_2...	35035.11	aP'	aD	a^3P'	a^3F'	
		45	296	270	391	
dD'_2...	43710.28	aP'	aD			
		217	398			
eD'_2...	43799.57	aP'	aD	bD		
		219	401	216		
aF_3...	22404.69	aD	cD	dD	bF'	cF'
		46	179	293	100	230
		cG	dG	a^3F'		
		218	325	175		
bF_3...	32857.76	aD	bD	aG	bG	a^3F'
		255	18	146	40	372
cF_3...	37622.63	aD	bD	aG	bG	a^3P'
		336	79	252	118	311
		a^3F'	a^3G			
		404	184			
dF_3...	40303.04	aD	bD	aG	bG	
		373	133	300	174	
eF_3...	41585.24	aD	bD	aF'	aG	
		387	161	8	317	
fF_3...	48365.09	aD	aF'	aG	bG	
		414	99	396	332	
aG'_4...	24694.81	bF'	cF'	aG	cG	dG
		61	173	17	160	286
		bH'	a^3F'			
		150	231			
bG'_4...	36000.25	aG	bG	dG	aH'	a^3G
		221	84	57	47	149
		a^3H'				
		86				
cG'_4...	38959.53	aG	bG	aH'	b^3F'	a^3H'
		277	144	90	285	152
dG'_4...	40883.30	bG	aH'	a^3F'		
		191	132	411		
eG'_4...	43674.31	aF'	aG	bG	aH'	
		31	354	248	198	
fG'_4...	46257.67	aF'	aG	bG	aH'	a^3H'
		63	384	298	251	301

Type	Term	Combinations				
aH_5...	34700.31	aG	bG	aH'	b^3F'	a^3H'
		189	62	32	200	69
bH_5...	41039.93	aG	bG	aH'	a^3H'	
		308	196	137	203	
cH_5...	44163.24	aG	aH'	b^3F'		
		366	215	369		
aI'_5...	40319.80	aH'	a^3H'			
		122	180			
$a^3P'_2$...	8602.42	a^3S'	b^3S'	c^3S'	d^3S'	a^3P
	109.94	60	276	367	397	73
$a^3P'_1$...	8492.48	b^3P	c^3P	d^3P	e^3P	f^3P
	55.79	206	233	304	358	377
$a^3P'_0$...	8436.69	g^3P	a^3D'	b^3D'	c^3D'	d^3D'
		400	5	72	103	155
		e^3D'	f^3D'	g^3D'	h^3D'	i^3D'
		190	315	331	349	363
		j^3D'	k^3D'	l^3D'	m^3D'	f^3F
		380	381	394	399	313
		g^3F	c^3G'	aP	bP	cP
		326	158	245	266	337
		dP	eP	bD'	cD'	cF
		342	386	117	270	311
		a^5S'	b^5S'	a^5P	b^5P	b^5D'
		66	306	116	292	77
		c^5D'				
		162				
$b^3P'_2$...	18145.40	b^3S'	c^3S'	b^3P	f^3P	g^3P
	83.86	78	194	27	220	279
$b^3P'_1$...	18061.54	d^3D'	e^3D'	f^3D'	g^3D'	i^3D'
	65.79	7	19	131	142	185
$b^3P'_0$...	17995.75					
$c^3P'_2$...	18911.55	c^3S'	c^3P	d^3P	e^3P	g^3P
	85.66	170	34	93	164	264
$c^3P'_1$...	18825.89	e^3D'	h^3D'	i^3D'	b^5S'	
	7.66	14	148	166	96	
$c^3P'_0$...	18818.23					
$d^3P'_2$...	46244.60	a^3S'	a^3D'			
		159	260			
a^3D_3...	17540.33	b^3P	c^3P	d^3P	e^3P	f^3P
	116.22	35	51	124	201	232
a^3D_2...	17424.11	g^3P	e^3D'	f^3D'	g^3D'	h^3D'
	54.52	290	26	140	156	178
a^3D_1...	17369.59	i^3D'	j^3D'	d^3F	e^3F	f^3F
		208	236	58	68	135
		g^3F	h^3F	b^5S'		
		154	223	129		

TABLE I—*Continued*

Type	Term	Combinations				
b^3D_3	48839.74	a^3D'	d^3D'	a^3F	a^5D'	a^5F
	115.40	305	107	314	333	356
b^3D_2	48724.34					
	−0.49					
b^3D_1	48724.83					
c^3D_3	49619.72	a^3D'	a^3F			
	48.03	318	330			
c^3D_2	49571.69					
$a^3F'_4$	386.88	a^3S'	a^3P	b^3P	a^3D'	b^3D'
	216.74	242	247	355	126	246
$a^3F'_3$	170.14	c^3D'	d^3D'	e^3D'	f^3D'	g^3D'
	170.14	283	319	343	405	408
$a^3F'_2$	0.00	h^3D'	i^3D'	j^3D'	k^3D'	l^3D'
		409	410	415	416	418
		m^3D'	a^3F	b^3F	c^3F	d^3F
		421	112	239	271	376
		e^3F	f^3F	g^3F	h^3F	i^3F
		382	403	407	413	417
		j^3F	a^3G'	b^3G'	c^3G'	d^3G'
		420	157	284	320	347
		e^3G'	f^3G'	g^3G'	a^3H	aD'
		402	412	419	353	169
		bD'	cD'	aF	bF	cF
		294	391	175	372	404
		aG'	dG'	a^5S'	a^5P	a^5D'
		231	411	243	288	91
		b^5D'	c^5D'	d^5D'	a^5F	b^5F
		249	323	393	65	302
		a^5G'	b^5G'			
		53	267			
$b^3F'_4$	11776.89	a^3P	b^3D'	c^3D'	d^3D'	e^3D'
	137.04	30	28	52	88	119
$b^3F'_3$	11639.85	f^3D'	g^3D'	h^3D'	i^3D'	j^3D'
	108.03	265	281	297	312	339
$b^3F'_2$	11531.82	k^3D'	l^3D'	m^3D'	b^3F	c^3F
		341	371	379	22	48
		d^3F	e^3F	f^3F	g^3F	i^3F
		168	182	259	274	362
		j^3F	b^3G'	c^3G'	d^3G'	e^3G'
		375	54	94	123	257
		f^3G'	cG'	aH	cH	a^5S'
		321	285	200	369	23
		c^5D'	b^5G'			
		92	45a			
$c^3F'_4$	37824.69	a^3D'	b^3D'	a^3F	c^3F	a^3G'
	164.72	82	13	87	2	56
$c^3F'_3$	37659.97					
	121.26					
$c^3F'_2$	37538.71					

Type	Term	Combinations				
$d^3F'_4$	39785.94	b^3D'	b^3F	b^3G'		
	144.96	33	38	12		
$d^3F'_3$	39640.98					
	114.09					
$d^3F'_2$	39526.89					
$e^3F'_4$	42107.06	a^3D'	a^3F	a^3G'	a^5D'	a^5F
	118.67	171	187	139	212	240
$e^3F'_3$	41988.39					
	116.52					
$e^3F'_2$	41871.87					
$f^3F'_4$	46530.45	a^3D'	a^3F	a^3G'		
		268	280	238		
$g^3F'_4$	47194.68	a^3F	a^3G'			
	156.52	289	250			
$g^3F'_3$	47038.16					
a^3G_5	15220.47	c^3F	d^3F	e^3F	f^3F	g^3F
	63.64	6	97	105	188	213
a^3G_4	15156.83	h^3F	i^3F	b^3G'	c^3G'	d^3G'
	48.71	262	303	15	42	59
a^3G_3	15108.12	e^3G'	g^3G'	a^3H	b^3H	c^3H
		183	310	70	138	224
		d^3H	cF	bG'		
		272	184	149		
b^3G_5	36200.94	a^3F	b^3F	a^3G'		
	68.73	67	3	37		
b^3G_4	36132.21					
	66.46					
b^3G_3	36065.75					
c^3G_5	41481.13	a^3F	a^3G'			
	112.27	167	125			
c^3G_4	41368.86					
	174.44					
c^3G_3	41194.42					
$a^3H'_6$	18192.66	c^3G'	d^3G'	e^3G'	f^3G'	g^3G'
	51.29	10	20	120	205	261
$a^3H'_5$	18141.37	a^3H	b^3H	c^3H	a^3I'	bG'
	104.09	29	80	153	141	86
$a^3H'_4$	18037.28	cG'	fG'	aH	bH	aI'
		152	301	69	203	180
$b^3H'_6$	45960.39	a^3G'				
	127.89	227				
$b^3H'_5$	45832.50					
	110.61					
$b^3H'_4$	45721.89					

TABLE I—*Continued*

Type	Term	Combinations				
a^3S_1'...	24921.19	a^3P'	d^3P'	a^3F'	aD	
		60	159	242	83	
b^3S_1'...	35439.43	a^3P'	b^3P'			
		276	78			
c^3S_1'...	40844.19	a^3P'	b^3P'	c^3P'		
		367	194	170		
d^3S_1'...	44857.89	a^3P'				
		397				
a^3P_2...	25493.78	a^3P'	a^3F'	b^3F'		
	−43.61	73	247	30		
a^3P_1...	25537.39					
b^3P_2...	31805.94	a^3P'	b^3P'	a^3D	a^3F'	
	80.19	206	27	35	355	
b^3P_1...	31725.75					
	39.85					
b^3P_0...	31685.90					
c^3P_2...	33114.49	a^3P'	c^3P'	a^3D	aD	
	23.94	233	34	51	256	
c^3P_1...	33090.55					
	5.41					
c^3P_0...	33085.14					
d^3P_2...	37325.47	a^3P'	c^3P'	a^3D	aD	a^5P'
	152.44	304	93	124	327	210
d^3P_1...	37173.03					
	82.38					
d^3P_0...	37090.65					
e^3P_2...	40467.04	a^3P'	c^3P'	a^3D	aD	
	82.46	358	164	201	374	
e^3P_1...	40384.58					
	14.82					
e^3P_0...	40369.76					
f^3P_2...	41928.59	a^3P'	b^3P'	a^3D	aD	
	−15.36	377	220	232	388	
f^3P_1...	41943.95					
	−15.51					
f^3P_0...	41959.46					
g^3P_2...	45178.06	a^3P'	b^3P'	c^3P'	a^3D	aD
	87.33	400	279	264	290	406
g^3P_1...	45090.73					
	50.03					
g^3P_0...	45040.70					

Type	Term	Combinations				
a^3D_3'...	20126.13	a^3P'	d^3P'	b^3D	c^3D	a^3F'
	120.05	5	260	305	318	126
a^3D_2'...	20006.08	c^3F'	e^3F'	f^3F'		
	68.20	82	171	268		
a^3D_1'...	19937.88					
b^3D_3'...	25643.76	a^3P'	a^3F'	b^3F'	c^3F'	d^3F'
	204.72	72	246	28	13	33
b^3D_2'...	25439.04	aD	a^5F'			
	121.16	95	102			
b^3D_1'...	25317.88					
c^3D_3'...	27480.14	a^3P'	a^3F'	b^3F'	aD	a^5P'
	62.04	103	283	52	134	21
c^3D_2'...	27418.10					
	62.94					
c^3D_1'...	27355.16					
d^3D_3'...	29912.33	a^3P'	b^3P'	b^3D	a^3F'	b^3F'
	143.63	155	7	107	319	88
d^3D_2'...	29768.70	aD	a^5F'			
	107.44	193	204			
d^3D_1'...	29661.26					
e^3D_3'...	31206.08	a^3P'	b^3P'	c^3P'	a^3D	a^3F'
	15.36	190	19	14	26	343
e^3D_2'...	31190.72	b^3F'	aD			
	6.71	119	225			
e^3D_1'...	31184.01					
f^3D_3'...	38159.71	a^3P'	b^3P'	a^3D	a^3F'	b^3F'
	182.93	315	131	140	405	265
f^3D_2'...	37976.78	aD				
	124.87	340				
f^3D_1'...	37851.91					
g^3D_3'...	38764.96	a^3P'	b^3P'	a^3D	a^3F'	b^3F'
	65.01	331	142	156	408	281
g^3D_2'...	38699.95	aD				
	45.72	351				
g^3D_1'...	38654.23					
h^3D_3'...	39715.51	a^3P'	c^3P'	a^3D	a^3F'	b^3F'
	29.41	349	148	178	409	297
h^3D_2'...	39686.10	aD				
	23.95	370				
h^3D_1'...	39662.15					
i^3D_3'...	40844.19	a^3P'	b^3P'	c^3P'	a^3D	a^3F'
	173.59	363	185	166	208	410
i^3D_2'...	40670.60	b^3F'	aD			
	114.53	312	378			
i^3D_1'...	40556.07					

TABLE I—*Continued*

Type	Term	Combinations				
$j^3D'_3$...	42311.31	a^3P'	a^3D	a^3F'	b^3F'	aD
	104.43	380	236	415	339	389
$j^3D'_2$...	42206.88					
	60.49					
$j^3D'_1$...	42146.39					
$k^3D'_3$...	42376.71	a^3P'	a^3F'	b^3F'	aD	
	106.98	381	416	341	390	
$k^3D'_2$...	42269.73					
	75.79					
$k^3D'_1$...	42193.94					
$l^3D'_3$...	44233.15	a^3P'	a^3F'	b^3F'		
	153.76	394	418	371		
$l^3D'_2$...	44079.39					
	103.77					
$l^3D'_1$...	43975.62					
$m^3D'_3$..	45206.34	a^3P'	a^3F'	b^3F'		
	142.40	399	421	379		
$m^3D'_2$..	45063.94					
	97.58					
$m^3D'_1$..	44966.36					
a^3F_4...	19573.96	b^3D	c^3D	a^3F'	c^3F'	e^3F'
	152.36	314	330	112	87	187
a^3F_3...	19421.60	f^3F'	g^3F'	b^3G	c^3G	bF′
	98.62	280	289	67	167	165
a^3F_2...	19322.98	b^5D				
		192				
b^3F_4...	25388.39	a^3F'	b^3F'	d^3F'	b^3G	a^5F'
	161.13	239	22	38	3	98
b^3F_3...	25227.26					
	119.82					
b^3F_2...	25107.44					
c^3F_4...	27025.66	a^3F'	b^3F'	c^3F'	a^3G	a^5F'
	132.66	271	48	2	6	136
c^3F_3...	26893.00					
	89.52					
c^3F_2...	26803.48					
d^3F_4...	33700.87	a^3D	a^3F'	b^3F'	a^3G	
	20.55	58	376	168	97	
d^3F_3...	33680.32					
	24.35					
d^3F_2...	33655.97					
e^3F_4...	34205.06	a^3D	a^3F'	b^3F'	a^3G	aD
	126.41	68	382	182	105	275
e^3F_3...	34078.65	aG				
	98.02	177				
e^3F_2...	33980.63					

Type	Term	Combinations				
f^3F_4...	37852.47	a^3P'	a^3D	a^3F'	b^3F'	a^3G
	108.51	313	135	403	259	188
f^3F_3...	37743.96	aD				
	89.19	338				
f^3F_2...	37654.77					
g^3F_4...	38670.73	a^3P'	a^3D	a^3F'	b^3F'	a^3G
	126.35	326	154	407	274	213
g^3F_3...	38544.38					
	93.09					
g^3F_2...	38451.29					
h^3F_4...	41624.13	a^3D	a^3F'	a^3G	aD	
	166.51	223	413	262	385	
h^3F_3...	41457.62					
	120.19					
h^3F_2...	41337.43					
i^3F_4...	43744.55	a^3F'	b^3F'	a^3G		
	161.41	417	362	303		
i^3F_3...	43583.14					
	115.59					
i^3F_2...	43467.55					
j^3F_4...	45041.02	a^3F'	b^3F'			
	118.02	420	375			
j^3F_3...	44923.00					
	97.74					
j^3F_2...	44825.26					
$a^3G'_5$...	21739.69	a^3F'	c^3F'	e^3F'	f^3F'	g^3F'
	151.23	157	56	139	238	250
$a^3G'_4$...	21588.46	b^3G	c^3G	b^3H'	g^5F'	c^5H'
	118.93	37	125	227	273	263
$a^3G'_3$...	21469.53					
$b^3G'_5$...	27750.16	a^3F'	b^3F'	d^3F'	a^3G	a^5F'
	135.45	284	54	12	15	147
$b^3G'_4$...	27614.71					
	115.80					
$b^3G'_3$...	27498.91					
$c^3G'_5$...	30039.35	a^3P'	a^3F'	b^3F'	a^3G	a^3H'
	68.22	158	320	94	42	10
$c^3G'_4$...	29971.13	a^5F'				
	56.34	207				
$c^3G'_3$...	29914.79					
$d^3G'_5$...	31628.76	a^3F'	b^3F'	a^3G	a^3H'	aD
	139.27	347	123	59	20	229
$d^3G'_4$...	31489.49	aG				
	115.64	121				
$d^3G'_3$...	31373.85					

TABLE I—*Continued*

Type	Term	Combinations				
$e^3G'_5$...	37690.37	a^3F'	b^3F'	a^3G	a^3H'	aD
	72.44	402	257	183	120	334
$e^3G'_4$...	37617.93					
	62.94					
$e^3G'_3$...	37554.99					
$f^3G'_5$...	41341.62	a^3F'	b^3F'	a^3H'	aD	bG
	86.18	412	321	205	383	199
$f^3G'_4$...	41255.44					
	85.62					
$f^3G'_3$...	41169.82					
$g^3G'_5$...	44375.57	a^3F'	a^3G	a^3H'		
	213.13	419	310	261		
$g^3G'_4$...	44162.44					
a^3H_6...	32013.61	a^3F'	a^3G	a^3H'		
	99.30	353	70	29		
a^3H_5...	31914.31					
	84.33					
a^3H_4...	31829.98					
b^3H_6..	35685.23	a^3G	a^3H'	bG		
	125.57	138	80	76		
b^3H_5..	35559.66					
	105.67					
b^3H_4..	35453.99					
c^3H_6...	39198.39	a^3G	a^3H'	aG	bG	
	46.25	224	153	282	151	
c^3H_5...	39152.14					
	36.15					
c^3H_4...	39115.99					
d^3H_6..	41995.39	a^3G				
	100.24	272				
d^3H_5..	41895.15					
	114.20					
d^3H_4..	41780.95					
$a^3I'_7$...	38779.97	a^3H'				
	110.94	141				
$a^3I'_6$...	38669.03					
	96.28					
$a^3I'_5$...	38572.75					
$a^5P'_3$...	14105.68	a^5S'	b^5S'	a^5P	b^5P	b^5D'
	77.21	4	211	25	181	9
$a^5P'_2$...	14028.47	c^5D'	d^5D'	d^3P	c^3D'	
	46.72	55	163	210	21	
$a^5P'_1$...	13981.75					
$b^5P'_3$...	42858.90	a^5D'				
	134.79	226				
$b^5P'_2$...	42724.11					
	112.53					
$b^5P'_1$...	42611.58					

Type	Term	Combinations				
b^5D_4..	42184.66	a^5D'	a^5F	a^3F		
	131.94	214	244	192		
b^5D_3..	42052.72					
	94.21					
b^5D_2..	41958.51					
	57.15					
b^5D_1...	41901.36					
	29.80					
b^5D_0..	41871.56					
c^5D_4...	44381.17	c^5D'	b^5F			
	126.78	36	50			
c^5D_3...	44254.39					
d^5D_4..	48186.11	a^5D'	a^5F			
	126.29	316	346			
d^5D_3..	48059.82					
e^5D_4...	49036.46	a^5D'	a^5F			
	12.03	335	360			
e^5D_3...	49024.43					
	109.36					
e^5D_2...	48915.07					
	55.56					
e^5D_1...	48859.51					
	57.19					
e^5D_0...	48802.32					
$a^5F'_5$...	6843.00	a^5D'	b^5D'	c^5D'	d^5D'	e^5D'
	100.21	11	113	209	307	392
$a^5F'_4$...	6742.79	a^5F	b^5F	b^5G'	b^3D'	d^3D'
	81.79	1	172	128	102	204
$a^5F'_3$...	6661.00	b^3F	c^3F	b^3G'	c^3G'	
	62.17	98	136	147	207	
$a^5F'_2$...	6598.83					
	41.97					
$a^5F'_1$...	6556.86					
$b^5F'_5$...	36351.43	a^5D'	a^5F	a^5G'		
	142.51	81	109	130		
$b^5F'_4$...	36208.92					
	112.45					
$b^5F'_3$...	36096.47					
	82.90					
$b^5F'_2$..	36013.57					
	54.50					
$b^5F'_1$...	35959.07					
$c^5F'_5$...	39412.78	a^5D'	a^5F	a^5G'	b^5G'	
	110.42	145	176	202	16	
$c^5F'_4$...	39302.36					
	87.98					
$c^5F'_3$...	39214.38					
	65.12					
$c^5F'_2$...	39149.26					
	42.01					
$c^5F'_1$...	39107.25					

TABLE I—*Continued*

Type	Term	Combinations			
$d^5F'_5$...	43330.07	a^5D'	a^5F	b^5F	a^5G'
	98.08	234	258	39	278
$d^5F'_4$...	43231.99				
	83.84				
$d^5F'_3$...	43148.15				
	67.23				
$d^5F'_2$...	43080.92				
	46.84				
$d^5F'_1$...	43034.08				
$e^5F'_5$...	46157.76	a^5D'	a^5F	a^5G'	
	150.14	287	309	324	
$e^5F'_4$...	46007.62				
	114.36				
$e^5F'_3$...	45893.26				
	80.25				
$e^5F'_2$...	45813.01				
	48.30				
$e^5F'_1$...	45764.71				
$f^5F'_5$...	47777.32	c^5D'	b^5F		
		85	106		
$g^5F'_5$...	48462.11	a^5D'	a^5F	a^5G'	a^3G'
	133.30	322	350	364	273
$g^5F'_4$...	48328.81				
	119.94				
$g^5F'_3$...	48208.87				
	101.45				
$g^5F'_2$...	48107.42				
	48.57				
$g^5F'_1$...	48058.85				
$h^5F'_5$...	48771.73	a^5D'	a^5F	a^5G'	
	99.07	329	352	368	
$h^5F'_4$...	48672.66				
	84.38				
$h^5F'_3$...	48588.28				
	69.07				
$h^5F'_2$...	48519.21				
a^5G_6...	42019.22	a^5F	a^5G'		
	115.74	237	253		
a^5G_5...	41903.48				
	84.78				
a^5G_4...	41818.70				
	61.23				
a^5G_3...	41757.47				
	43.12				
a^5G_2...	41714.35				
b^5G_6...	45904.73	b^5F	b^5G'		
	148.28	74	108		
b^5G_5...	45756.45?				
	45.17				
b^5G_4...	45711.28				
	21.39				
b^5G_3...	45689.89				

Type	Term	Combinations			
c^5G_6...	47446.84	a^5F	a^5G'		
	166.15	328	344		
c^5G_5...	47280.69				
	140.83				
c^5G_4...	47139.86				
	109.58				
c^5G_3...	47030.28				
	86.37				
c^5G_2...	46943.91				
d^5G_6...	48233.47	a^5F	a^5G'		
	114.00	348	357		
d^5G_5...	48119.47				
	101.39				
d^5G_4...	48018.08				
	81.29				
d^5G_3...	47936.79				
	66.18				
d^5G_2...	47870.61				
$a^5H'_7$...	42205.59	a^5F	a^5G'		
	81.82	241	254		
$a^5H'_6$...	42123.77				
	105.76				
$a^5H'_5$...	42018.01				
	100.96				
$a^5H'_4$...	41917.05				
	93.86				
$a^5H'_3$...	41823.19				
$b^5H'_7$..	44134.65	b^5G'			
	83.28	75			
$b^5H'_6$...	44051.37				
	79.82				
$b^5H'_5$..	43971.55				
	69.81				
$b^5H'_4$...	43901.74				
	57.92				
$b^5H'_3$...	43843.82				
$c^5H'_7$...	48262.83	a^5F	a^5G'	a^3G'	
	156.00	345	359	263	
$c^5H'_6$...	48106.83				
	112.51				
$c^5H'_5$...	47994.32				
	80.71				
$c^5H'_4$...	47913.61				
	72.99				
$c^5H'_3$...	47840.62				
$a^5S'_2$...	25102.88	a^5P'	a^3P'	a^3F'	b^3F'
		4	66	243	23
$b^5S'_2$...	37359.13	a^5P'	a^3P'	c^3P'	a^3D
		211	306	96	129

TABLE I—*Continued*

Type	Term	Combinations				
a^5P_3...	27887.74	a^5P'	a^3P'	a^3F'		
	147.55	25	116	288		
a^5P_2...	27740.19					
	74.62					
a^5P_1...	27665.57					
b^5P_3...	36414.58	a^5P'	a^3P'			
	73.91	181	292			
b^5P_2...	36340.67					
	42.24					
b^5P_1...	36298.43					
$a^5D'_4$...	18695.23	b^5P'	b^5D	d^5D	e^5D	a^5F'
	101.24	226	214	316	335	11
$a^5D'_3$...	18593.99	b^5F'	c^5F'	d^5F'	e^5F'	g^5F'
	68.92	81	145	234	287	322
$a^5D'_2$...	18525.07	h^5F'	b^3D	a^3F'	e^3F'	
	42.21	329	333	91	212	
$a^5D'_1$...	18482.86					
	20.03					
$a^5D'_0$...	18462.83					
$b^5D'_4$...	25926.82	a^5P'	a^5F'	a^3P'	a^3F'	
	129.22	9	113	77	249	
$b^5D'_3$...	25797.60					
	97.65					
$b^5D'_2$...	25699.95					
	64.21					
$b^5D'_1$...	25635.74					
	30.71					
$b^5D'_0$...	25605.03					
$c^5D'_4$...	30060.34	a^5P'	c^5D	a^5F'	f^5F'	a^3P'
	74.10	55	36	209	85	162
$c^5D'_3$...	29986.24	a^3F'	b^3F'			
	78.95	323	92			
$c^5D'_2$...	29907.29					
	52.03					
$c^5D'_1$...	29855.26					
	26.10					
$c^5D'_0$...	29829.16					
$d^5D'_4$...	35757.51	a^5P'	a^5F'	a^3F'		
	104.56	163	307	393		
$d^5D'_3$...	35652.95					
	75.81					
$d^5D'_2$...	35577.14					
	49.38					
$d^5D'_1$...	35527.76					
	24.36					
$d^5D'_0$...	35503.40					
$e^5D'_4$...	42092.52	a^5F'				
	106.59	392				
$e^5D'_3$...	41985.93					
	79.32					
$e^5D'_2$...	41906.61					
	52.60					
$e^5D'_1$...	41854.01					
	31.02					
$e^5D'_0$...	41822.99					
a^5F_5...	17215.44	b^5D	d^5D	e^5D	a^5F'	b^5F'
	140.13	244	346	360	1	109
a^5F_4...	17075.31	c^5F'	d^5F'	e^5F'	g^5F'	h^5F'
	113.89	176	258	309	350	352
a^5F_3...	16961.42	a^5G	c^5G	d^5G	a^5H'	c^5H'
	86.23	237	328	348	241	345
a^5F_2...	16875.19	b^3D	a^3F'	e^3F'		
	58.00	356	65	240		
a^5F_1...	16817.19					
b^5F_5...	28896.08	c^5D	a^5F'	d^5F'	f^5F'	b^5G
	107.69	50	172	39	106	74
b^5F_4...	28788.39	a^3F'				
	85.69	302				
b^5F_3...	28702.70					
	63.88					
b^5F_2...	28638.82					
	42.37					
b^5F_1...	28596.45					
$a^5G'_6$...	16458.71	b^5F'	c^5F'	d^5F'	e^5F'	g^5F'
	191.20	130	202	278	324	364
$a^5G'_5$...	16267.51	h^5F'	a^5G	c^5G	d^5G	a^5H'
	161.43	368	253	344	357	254
$a^5G'_4$...	16106.08	c^5H'	a^3F'			
	130.49	359	53			
$a^5G'_3$...	15975.59					
	98.41					
$a^5G'_2$...	15877.18					
$b^5G'_6$...	26910.69	a^5F'	c^5F'	b^5G	b^5H'	a^3F'
	137.71	128	16	108	75	267
$b^5G'_5$...	26772.98	b^3F'				
	115.57	45a				
$b^5G'_4$...	26657.41					
	92.98					
$b^5G'_3$...	26564.43					
	70.06					
$b^5G'_2$...	26494.37					

Table II contains all the lines of *Ti* I which have been classified, and all the unclassified lines of intensity 3 or more on King's scale, or 2 or more on that of Meggers. The first column gives a reference to the source of the measures (see notes at end of the table); the second, the observed wave-length; the third, the excess in units of 0.01 A of this above the value computed from the term values of Table I. The fourth column gives the intensity, and the fifth the temperature class. When the latter is given, both data are taken from King's paper (or in a few instances from estimates made by the writer on the photographs, in which case the intensity in the furnace and the temperature class are given in brackets). Otherwise the intensity is that given by the observer mentioned in the first column. These latter intensities are far from homogeneous, but, as most of the lines are faint anyhow, it is not worth while to attempt to correct them. They are given in parentheses in the table. The sixth column gives the vacuum frequency, ν; and the seventh, the terms whose combination accounts for the line—two entries, in the cases where there is good reason to believe that the line is an unresolved blend. In the last column is an index number to facilitate the identification of the multiplets. The first line in the table and all lines in the same multiplet are numbered "1"; the next unappropriated line and all in the multiplet to which it belongs, "2"; and so on.

TABLE II

Ti I—IDENTIFIED ARC LINES

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
6........	9787.60	−3	(0)	....	10214.22	$a^5F'_3-a^5F_2$	1
6........	9770.20	−8	(1)	....	10232.40	$a^5F'_5-a^5F_4$	1
1........	9743.58	−3	(1h)	....	10260.36	$a^5F'_1-a^5F_1$	1
1........	9728.33	−8	(1)	....	10276.44	$a^5F'_2-a^5F_2$	1
1........	9705.63	−6	(1)	....	10300.48	$a^5F'_3-a^5F_3$	1
1........	9675.57	+4	(1)	....	10332.48	$a^5F'_4-a^5F_4$	1
1........	9647.55	+10	(1h)	....	10362.48	$a^5F'_2-a^5F_3$	1
1........	9638.26	−3	(2h)	....	10372.47	$a^5F'_5-a^5F_5$	1
1........	9599.44	−10	(1)	....	10414.42	$a^5F'_3-a^5F_4$	1
1........	9546.06	0	(1)	....	10472.65	$a^5F'_4-a^5F_5$	1
1........	9285.02	−9	(1)	....	10767.08	$c^3F_3-c^3F'_3$	2
1........	9257.62	+7	(1)	....	10798.95	$c^3F_4-c^3F'_4$	2
1........	9246.18	+21	(1)	....	10812.31	$b^3F_4-b^3G_5$	3
1........	9167.55	−8	(1)	....	10905.05	$b^3F_3-b^3G_4$	3
1........	9123.09	+10	(1)	....	10958.19	$b^3F_2-b^3G_3$	3
1........	9090.68	−5	(1)	....	10997.26	$a^5P'_3-a^5S'_2$	4
1........	9027.28	−7	(1)	....	11074.50	$a^5P'_2-a^5S'_2$	4
1........	8989.40	−2	(2)	....	11121.16	$a^5P'_1-a^5S'_2$	4
6........	8766.59	−12	(3−)	....	11403.82	$a^3P'_2-a^3D'_2$	5
1........	8734.69	−5	(1h)	....	11445.47	$a^3P'_1-a^3D'_1$	5
1........	8692.29	−7	(1)	....	11501.28	$a^3P'_0-a^3D'_1$	5
1........	8682.93	−7	(2)	....	11513.69	$a^3P'_1-a^3D'_2$	5
1........	8675.33	−5	(2)	....	11523.78	$a^3P'_2-a^3D'_3$	5
1........	8548.06	+1	(2)	....	11695.35	$a^3G_3-c^3F_2$	6
1........	8539.30	−14	(1)	....	11707.35	$b^3P'_1-d^3D'_2$	7
1........	8518.20	−13	(4)	....	11736.35	$a^3G_4-c^3F_3$	6
1*.......	8495.94	−8 −12	(1)	....	11767.09	$b^3P'_2-d^3D'_3$ $aF'-eF$	7 8
1........	8468.45	−8	(3)	....	11805.30	$a^3G_5-c^3F_4$	6
1........	8467.13	......	(2)	....	11807.14	....	......
1........	8457.03	−7	(2h)	....	11821.24	$a^5P'_3-b^5D'_4$	9
1........	8450.89	−4	(3)	....	11829.82	$a^3H'_5-c^3G'_4$	10
1........	8438.90	+4	(3)	....	11846.64	$a^3H'_6-c^3G'_5$	10
1........	8435.64	−1	(5)	....	11851.21	$a^5F'_4-a^5D'_3$	11
1........	8434.89	−2	(4)	....	11852.26	$a^5F'_5-a^5D'_4$	11
1........	8426.46	−4	(4)	....	11864.13	$a^5F'_3-a^5D'_2$	11
1........	8412.34	−1	(3)	....	11884.04	$a^5F'_2-a^5D'_1$	11
10........	8402.47	−1	(0)	....	11898.00	$a^3H'_5-c^3G'_5$	10
1........	8396.85	+1	(2)	....	11905.96	$a^5F'_1-a^5D'_0$	11
12*.......	8382.72	−2	(2)	....	11926.03	$a^5F'_1-a^5D'_1$	11
12*.......	8382.45	−13	(2)	....	11926.42	$a^5F'_2-a^5D'_2$	11
1........	8377.83	0	(2)	....	11932.99	$a^5F'_3-a^5D'_3$	11
1........	8364.18	−1	(2)	....	11952.46	$a^5F'_4-a^5D'_4$	11
1........	8353.12	−6	(2)	....	11968.30	$a^5F'_1-a^5D'_2$	11
1........	8334.42	+1	(2)	....	11995.15	$a^5F'_2-a^5D'_3$	11
1........	8312.89	+4	(2)	....	12026.21	$b^3G'_4-d^3F'_3$	12
1........	8311.71	+4	(2)	....	12027.92	$b^3G'_3-d^3F'_2$	12
1........	8307.41	+6	(1)	....	12034.15	$a^5F'_3-a^5D'_4$	11
1........	8306.27	−1	(2h)	....	12035.80	$b^3G'_5-d^3F'_4$	12
1........	8207.32	+1	(1n?)	....	12180.91	$b^3D'_3-c^3F'_4$	13
1*.......	8180.45	+1 −6	(1n?)	....	12220.92	$b^3D'_2-c^3F'_3$ $b^3D'_1-c^3F'_2$	13 13

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multi-plet
1	8131.40	− 7	(1)		12294.64	$c^3P'_2-e^3D'_3$	14
12	8089.71	+ 8	(0)		12358.00	$c^3P'_1-e^3D'_1$	14
12	8084.96	−28	(1)		12365.25	$c^3P'_1-e^3D'_2$	14
12	8084.42	−20	(0)		12366.09	$c^3P'_0-e^3D'_1$	14
1	8068.21	− 9	(2)		12390.93	$a^3G_3-b^3G'_3$	15
1	8064.09	......	(2)		12397.25	....	......
1	8024.83	− 1	(2)		12457.90	$a^3G_4-b^3G'_4$	15
1	7996.49	+ 2	(3)		12502.06	$h^5G'_6-c^5F'_5$	16
1*	7978.87	+ 2 −19	(4)		12529.66	$a^3G_5-b^3G'_5$ $b^5G'_5-c^5F'_4$	15 16
1	7961.59	+ 7	(2)		12556.86	$b^5G'_4-c^5F'_3$	16
1	7949.11	−15	(3)		12576.58	$aG-aG'$	17
1	7943.91	+ 1	(1h)		12584.81	$b^5G'_3-c^5F'_2$	16
1	7926.34	+11	(1)		12612.70	$b^5G'_2-c^5F'_1$	16
12	7903.98	−12	(0)		12648.31	$bD-bF$	18
12	7663.38	+ 4	(0)		13045.26	$b^3P'_2-e^3D'_2$	19
1	7654.46	− 1	(2)		13060.69	$b^3P'_2-e^3D'_3$	19
12	7618.33	−10	(0)		13122.65	$b^3P'_1-e^3D'_1$	19
1	7614.49	− 4	(1p?)		13129.25	$b^3P'_1-e^3D'_2$	19
12	7580.55	+15	(1)		13188.01	$b^3P'_0-e^3D'_1$	19
1	7496.12	0	(2)		13336.57	$a^3H'_4-d^3G'_3$	20
1	7489.61	− 2	(2)		13348.16	$a^3H'_5-d^3G'_4$	20
1	7474.93	+ 5	(1)		13374.37	$a^5P'_3-c^3D'_3$	21
1	7440.58	− 1	(3)		13436.12	$a^3H'_6-d^3G'_5$	20
6	7423.12	− 7	(2−)		13467.72	$b^3F'_3-b^3F_2$	22
1	7366.58	− 2	(1)		13571.09	$b^3F'_2-a^5S'_2$	23
1	7364.11	− 1	2	IV	13575.65	$b^3F'_2-b^3F_2$	22
1	7357.73	0	3	IV	13587.41	$b^3F'_3-b^3F_3$	22
1	7352.14	+ 1	(1)		13597.74	$aP'-aP$	24
1	7344.69	− 2	4	IV	13611.54	$b^3F'_4-b^3F_4$	22
1	7332.26	− 5	(1)		13634.61	$a^5P'_3-a^5P_2$	25
1	7330.97	+ 5	(1)		13637.01	$a^5P'_2-a^5P_1$	25
12	7323.71	− 8	(0)		13650.54	$a^3D_3-e^3D'_2$	26
1	7318.43	+ 9	(2)		13660.38	$b^3P'_2-b^3P_2$	27
12	7315.52	− 3	(1)		13665.81	$a^3D_3-e^3D'_3$	26
12	7305.87	− 4	(1)		13683.90	$a^5P'_1-a^5P_1$	25
1	7299.67	− 2	(2)		13695.48	$b^3F'_2-b^3F_3$	22
12	7281.74	......	(3h)		13729.20	....	......
3	7273.76?	+ 8	(0)		13744.26	$b^3P'_1-b^3P_2$	27
3	7271.47?	− 3	(0)		13748.60	$b^3F'_3-b^3F_4$	22
3	7266.24?	− 3	(0)		13758.50	$a^5P'_1-a^5P_2$	25
12	7265.32	−19	(0)		13760.25	$a^3D_2-e^3D'_1$	26
12	7261.86	− 9	(1)		13766.78	$a^3D_2-e^3D'_2$	26
1*	7253.76	− 6 −10	(1)		13782.17	$a^5P'_3-a^5P_3$ $a^3D_2-e^3D'_3$	25 26
1	7251.74	+ 3	8	III	13786.00	$b^3F'_2-b^3D'_1$	28
1	7244.82	+ 1	10	III	13799.17	$b^3F'_3-b^3D'_2$	28
12	7236.94	+12	(1)		13814.19	$a^3D_1-e^3D'_1$	26
12	7233.44	+ 2	(1)		13820.91	$a^3H'_6-a^3H_6$	29
12	7233.31	− 1	(1)		13821.14	$a^3D_1-e^3D'_2$	26
1	7216.19	+ 1	5	III	13853.92	$b^3F'_3-a^3P_2$	30
12	7214.97	−13	(0)		13856.25	$aF'-eG'$	31
12	7213.3	−20	(1)		13859.66	$a^5P'_2-a^5P_3$	25

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
1........	7209.44	− 2	20	III	13866.90	$b^3F'_4-b^3D'_3$	28
1........	7189.92	+ 6	2	IV?	13904.54	$aH'-aH$	32
3........	7188.59	+ 5	(0)	....	13907.12	$b^3F'_2-b^3D'_2$	28
6........	7160.33	− 2	(2)	....	13962.00	$b^3F'_2-a^3P_2$	30
1........	7138.92	+ 2	(1, Ti?)	....	14003.87	$b^3F'_3-b^3D'_3$	28
1........	7069.11	+ 1	2	IV	14142.16	$b^3D'_3-d^3F'_4$	33
1........	7050.68	− 6	(1)	....	14179.13	$c^3P'_2-c^3P_1$	34
3........	7039.36?	0	(1)	....	14201.93	$b^3D'_2-d^3F'_3$	33
1........	7038.83	− 2	6	IV	14202.99	$c^3P'_2-c^3P_2$	34
1........	7035.85	0	(2)	....	14209.02	$b^3D'_1-d^3F'_2$	33
1........	7010.94	−12	(1)	....	14259.50	$c^3P'_1-c^3P_0$	34
1........	7008.32	− 8	(1)	....	14264.83	$c^3P'_1-c^3P_1$	34
12........	7007.81	−14	(1)	....	14265.90	$a^3D_3-b^3P_2$	35
3........	7006.68	0	(0)	....	14268.16	$c^5D'_3-c^5D_3$	36
3........	7004.60	− 4	(1)	....	14272.41	$c^3P'_0-c^3P_1$	34
1........	6996.69	+ 3	(1)	....	14288.54	$c^3P'_1-c^3P_2$	34
12........	6990.31	0	(1)	....	14301.63	$a^3D_2-b^3P_1$	35
12........	6983.23	+12	(1)	....	14316.07	$a^3D_1-b^3P_0$	35
12........	6980.39	− 1	(1)	....	14320.85	$c^5D'_4-c^5D_4$	36
12........	6963.93	+17	(0)	....	14355.80	$a^3D_1-b^3P_1$	35
12........	6946.10	− 4	(0)	....	14392.61	$a^3G'_5-b^3G_4$	37
3........	6943.71	0	(2)	....	14397.56	$b^3F_4-d^3F'_4$	38
3........	6938.88?	.....	(3)	....	14407.58	....	......
12........	6935.88	− 3	(1)	....	14413.79	$b^3F_3-d^3F'_3$	38
12........	6933.14	− 3	(1)	....	14419.51	$b^3F_2-d^3F'_2$	38
3........	6926.16	− 3	(2)	....	14434.05	$b^5F_5-d^5F'_5$	39
11........	6913.03	−10	(2)	....	14461.46	$a^3G'_5-b^3G_5$	37
3........	6911.18	.....	(2)	....	14465.33	....	......
3........	6873.99	+ 8	(2)	....	14543.59	$a^3G'_4-b^3G_4$	37
1........	6861.47	+ 1	6	III	14570.13	$bG-bF$	40
3........	6854.30	− 2	(1)	....	14585.36	$cP-bP'$	41
12........	6849.15	− 5	(2)	....	14596.33	$a^3G'_3-b^3G_3$	37
12........	6841.65	+ 4	(0)	....	14612.40	$a^3G'_4-b^3G_5$	37
12........	6818.12	− 4	(0)	....	14662.77	$a^3G'_3-b^3G_4$	37
12........	6751.94	+ 7	(0)	....	14806.52	$a^3G_3-c^3G'_3$	42
12........	6748.43	+ 5	(1)	....	14814.18	$a^3G_4-c^3G'_4$	42
12........	6746.42	+13	(1)	....	14818.60	$a^3G_5-c^3G'_5$	42
1........	6743.14	+ 3	10	III A	14825.80	$aD-aD'$	43
4........	6716.68	− 8	(1)	....	14884.21	$aP'-bP$	44
3........	6677.25	+ 1	(0)	....	14972.11	$aP'-cD'$	45
1........	6666.57	0	(2n)	....	14996.09	$b^3F'_4-b^5G'_5$	45a
1........	6599.12	+ 2	12	III A	15149.36	$aD-aF$	46
1........	6575.19	+ 4	3	V	15204.50	$aH'-bG'$	47
3........	6565.62	.....	4	V	15226.65	....	......
1........	6556.08	− 2	25	III	15248.81	$b^3F'_4-c^3F_4$	48
1........	6554.23	+ 1	20	III	15253.13	$b^3F'_3-c^3F_3$	48
1........	6546.26	− 1	20	III	15271.68	$b^3F'_2-c^3F_2$	48
1........	6508.15	+ 3	3	III A	15361.11	$b^3F'_2-c^3F_3$	48
1........	6497.71	0	3	III A	15385.80	$b^3F'_3-c^3F_4$	48
1........	6465.56	+ 4	(2)	....	15462.29	$aS'-bP'$	49
1........	6464.02	+ 1	(1)	....	15465.98	$b^5F_4-c^5D_3$	50
1........	6456.06	+ 1	(2d?)	....	15485.06	$b^5F_5-c^5D_4$	50
1........	6454.22	.....	(2)	....	15489.47	....	......

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multi-plet
1........	6446.27	......	(2)	....	15508.57	....	......
12........	6419.15	− 8	(2)	....	15574.35	$a^3D_3-c^3P_2$	51
12........	6381.39	+ 5	(1)	....	15666.31	$a^3D_2-c^3P_1$	51
12........	6371.75	+15	(1)	....	15690.02	$a^3D_2-c^3P_2$	51
1........	6366.38	+ 3	8	III	15703.18	$b^3F'_4-c^3D'_3$	52
12†.......	6364.92	+13	[2]	[III A]	15706.73	$a^3F'_3-a^5G'_2$	53
12........	6361.41	0	(1)	....	15715.55	$a^3D_1-c^3P_0$	51
12†.......	6359.88	+ 3	[8]	[II A]	15719.12	$a^3F'_4-a^5G'_4$	53
12........	6359.20	− 1	(0)	....	15720.99	$a^3D_1-c^3P_1$	51
1........	6336.10	+ 1	8	III	15778.22	$b^3F'_3-c^3D'_2$	52
12†.......	6325.22	+ 2	[10]	[II A]	15805.40	$a^3F'_3-a^5G'_3$	53
4........	6318.00	− 3	5	III A	15823.42	$b^3F'_2-c^3D'_1$	52
1........	6312.23	− 3	10	III	15837.89	$b^3F'_4-b^3G'_4$	54
12........	6311.25	− 2	(1)	(III A)	15840.34	$b^3F'_3-c^3D'_3$	52
1........	6303.76	− 4	10	III	15859.16	$b^3F'_3-b^3G'_3$	54
12........	6298.07	0	(00)	....	15873.52	$a^5P'_1-c^5D'_1$	55
12†.......	6296.66	+ 6	[12]	[II A]	15877.04	$a^3F'_2-a^5G'_2$	53
12........	6295.93	+ 9	(0)	....	15878.60	$a^5P'_2-c^5D'_2$	55
1*†‡.....	6295.30	{+ 5 + 2}	[2]	[III A]	15880.50	{$a^3F'_4-a^5G'_5$ $a^5P'_3-c^5D'_3$	53 55
12........	6277.51	+ 2	(00)	....	15925.49	$a^5P'_1-c^5D'_2$	55
12†.......	6273.39	0	[6]	[II A]	15935.94	$a^3F'_3-a^5G'_4$	53
12........	6266.02	− 1	(1)	(III)	15954.69	$a^5P'_3-c^5D'_4$	55
12........	6264.80	− 1	(0)	....	15957.80	$a^5P'_2-c^5D'_3$	55
1........	6261.10	− 5	35	II	15967.22	$b^3F'_2-b^3G'_3$	54
1........	6258.70	− 3	50	II	15973.35	$b^3F'_4-b^3G'_5$	54
1........	6258.10	− 1	40	II	15974.88	$b^3F'_3-b^3G'_4$	54
12†.......	6257.72	+ 5	[2]	[III A]	15975.46	$a^3F'_2-a^5G'_3$	53
1........	6222.56	......	(2)	....	16066.12	....	......
1........	6221.42	+ 5	8	III	16069.06	$a^3G'_3-c^3F'_2$	56
1........	6220.45	− 2	12	III	16071.57	$a^3G'_4-c^3F'_3$	56
1........	6215.24	− 2	20	III	16085.04	$a^3G'_5-c^3F'_4$	56
2........	6199.64	+ 8	(0)	....	16125.53	$bG'-dG$	57
1........	6186.15	− 5	3	III	16160.68	$a^3D_3-d^3F_4$	58
1........	6174.47	−31	(2n)	....	16191.25	$a^3G'_3-c^3F'_3$?	56
1........	6159.02	0	(2n)	....	16231.86	$a^3D_2-d^3F_2$	58
1........	6149.81	+ 2	2	III	16256.17	$a^3D_2-d^3F_3$	58
1........	6146.22	+ 3	3	III	16265.66	$a^3G_3-d^3G'_3$	59
1........	6138.38	− 2	1	IV	16286.44	$a^3D_1-d^3F_2$	58
1........	6126.21	− 1	20	II	16318.80	$a^3P'_2-a^3S'_1$	60
1........	6121.03	+ 2	3	III	16332.61	$a^3G_4-d^3G'_4$	59
1........	6098.70	+ 3	7	III	16392.41	$aG'-bF'$	61
1........	6092.79	− 1	4	III	16408.31	$a^3G_5-d^3G'_5$	59
1........	6091.17	+ 1	20	III	16412.67	$bG-aH$	62
1........	6085.22	0	20	II	16428.71	$a^3P'_1-a^3S'_1$	60
1........	6081.31	+ 3	(1)	....	16439.28	$aF'-fG'$	63
1........	6070.98	+ 4	(1)	....	16467.25	$aP-dD$	64
1........	6064.64	− 1	9	II A	16484.47	$a^3P'_0-a^3S'_1$	60
12........	6059.27	......	[2]	[III A]	16499.06	....	......
11†.......	6031.71	+ 3	(0)	....	16574.47	$a^3F'_4-a^5F_3$	65
3........	6018.56?	−11	(0)	....	16610.69	$a^3P'_1-a^5S'_2$	66
12........	6012.53	− 5	(1)	....	16627.11	$a^3F_4-b^3G_5$	67
3........	6002.70?	− 1	(0)	....	16654.57	$a^3D_2-e^3F_3$	68

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
1	5999.66	+1	8	III	16663.00	$a^3H'_4-aH$	69
7	5999.00	−4	4n	IV	16664.83	$a^3D_3-e^3F_4$	68
4	5996.01	0	2	III	16673.15	$a^3G_4-a^3H_4$	70
4	5995.68	+6	2	V	16674.07	$bD'-cD$	71
4	5988.58	0	2	III	16693.83	$a^3G_5-a^3H_5$	70
11†	5984.59	+3	(1)	(III A)	16704.96	$a^3F'_3-a^5F_2$	65
12	5982.52	−2	(0)	(III A)	16710.66	$a^3F_3-b^3G_4$	67
12	5980.89	+5	(1)	(III A)	16715.31	$a^3P'_2-b^3D'_1$	72
1	5978.54	0	25	II	16721.87	$a^3G_3-a^3H_4$	70
12	5971.07	−1	(0)	....	16742.80	$a^3F_2-b^3G_3$	67
1	5965.83	−1	30	II	16757.50	$a^3G_4-a^3H_5$	70
1	5953.16	−1	30	II	16793.16	$a^3G_5-a^3H_6$	70
12†	5944.65	0	(0)	....	16817.20	$a^3F'_2-a^5F_1$	65
1	5941.73	−3	12	II A	16825.47	$a^3P'_1-b^3D'_1$	72
11†	5940.66	+2	(0)	....	16828.49	$a^3F'_4-a^5F_5$	65
1	5937.79	0	6	III A	16836.62	$a^3P'_2-b^3D'_2$	72
1	5922.11	−1	18	II	16881.21	$a^3P'_0-b^3D'_1$	72
1	5918.56	+1	10	II	16891.33	$a^3P'_2-a^3P_2$	73
11†	5913.71	0	(1)	....	16905.18	$a^3F'_3-a^5F_4$	65
1	5903.33	+1	5	III A	16934.90	$a^3P'_2-a^3P_1$	73
1	5899.29	+2	25	II	16946.50	$a^3P'_1-b^3D'_2$	72
1	5880.30	+2	5	III A	17001.23	$a^3P'_1-a^3P_2$	73
3*	5877.77	{+3 +1}	(1)	....	17008.55	{$b^5F_5-b^5G_6$ $b^5F_3-b^5G_4$}	74 74
1	5866.45	−1	35	II	17041.38	$a^3P'_2-b^3D'_3$	72
1	5863.10	−1	(1n)	....	17051.10	$b^5F_2-b^5G_3$	74
11	5832.47	+1	(1)	(IV)	17140.66	$b^5G'_6-b^5H'_6$	75
1	5823.76	+3	3	III	17166.29	$bG-b^3H_4$	76
12	5814.00	0	(1)	(III A)	17195.13	$a^3P'_2-b^5D'_3$	77
2	5812.83	0	(1)	(IV)	17198.58	$b^5G'_5-b^5H'_5$	75
12	5809.75	−6	(0)	(IV A)	17207.65	$a^3P'_1-b^5D'_2$	77
11	5804.26	0	5n	IV	17223.96	$b^5G'_6-b^5H'_7$	75
2	5797.45	+1	(1)	(IV)	17244.31	$b^5G'_4-b^5H'_4$	75
11	5785.97	−1	5n	IV	17278.41	$b^5G'_5-b^5H'_6$	75
12	5785.66	+1	(1)	(IV)	17279.36	$b^5G'_3-b^5H'_3$	75
7	5780.81	+6	2	III	17293.84	$b^3P'_2-b^3S'_1$	78
1	5774.02	−1	5n	IV	17314.17	$b^5G'_4-b^5H'_5$	75
1	5766.33	+2	4n	IV	17337.26	$b^5G'_3-b^5H'_4$	75
1	5762.25	−3	4n	IV	17349.53	$b^5G'_2-b^5H'_3$	75
1	5752.89	+5	1	IV	17377.75	$b^3P'_1-b^3S'_1$	78
1	5741.28	+3	1	IV	17412.90	$bD-cF$	79
1	5740.04	+1	4	IV	17416.67	$a^3H'_4-b^3H_4$	80
1	5739.50	0	9	III	17418.30	$a^3H'_5-b^3H_5$	80
1	5720.49	+1	3	III	17476.19	$a^5D'_1-b^5F'_1$	81
1	5716.48	+2	4	III	17488.44	$a^5D'_2-b^5F'_2$	81
7	5715.13	0	9	III	17492.57	$a^3H'_6-b^3H_6$	80
1	5713.93	0	3	IV	17496.25	$a^5D'_0-b^5F'_1$	81
7	5711.94	+5	4	IV	17502.34	$a^5D'_3-b^5F'_3$	81
1	5708.27	+3	3	IV	17513.59	$a^5D'_4-b^5F'_4$	81
1	5702.69	−1	6	III	17530.73	$a^5D'_1-b^5F'_2$	81
1	5689.47	−2	10	III	17571.47	$a^5D'_2-b^5F'_3$	81
1	5679.95	−3	2	III	17600.92	$a^3D'_1-c^3F'_2$	82
1	5675.41	−3	9	III A	17615.01	$a^5D'_3-b^5F'_4$	81

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multi-plet
4	5662.91	0	4	III	17653.88	$a^3D'_2-c^3F'_3$	82
1	5662.16	0	12	III	17656.21	$a^5D'_4-b^5F'_5$	81
12	5659.11	+5	(3)	(III A)	17665.74	$aD-a^3S'_1$	83
1	5648.63	+2	5	IV	17698.51	$a^3D'_3-c^3F'_4$	82
1	5644.14	+1	18	III	17712.59	$bG-bG'$	84
2	5642.79	+5	(1)	....	17716.83	$c^5D'_4-f^5F'_5$	85
1	5629.39	......	(2n?)	....	17759.00	....	......
2	5600.80	......	(2)	....	17849.66	....	......
1	5597.92	+1	(2n)	....	17858.84	$a^3H'_5-bG'$	86
2	5597.69	......	(3)	....	17859.57	....	......
1	5565.48	+1	9	III	17962.93	$a^3H'_4-bG'$	86
2	5527.61	0	(1)	....	18086.00	$a^3F_4-c^3F'_3$	87
1	5514.54	0	25	II	18128.86	$b^3F'_3-d^3D'_2$	88
7	5514.36	0	20	II	18129.45	$b^3F'_2-d^3D'_1$	88
1	5512.54	0	25	II	18135.44	$b^3F'_4-d^3D'_3$	88
7	5511.80	+3	2	III A	18137.87	$aP'-aS'$	89
1	5503.89	−2	8	III	18163.93	$aH'-cG'$	90
11†	5490.82	−2	(1)	(I A)	18207.17	$a^3F'_4-a^5D'_3$	91
7	5490.16	−1	12	II	18209.37	$b^3F'_4-c^5D'_3$	92
7	5488.24	0	5	III	18215.73	$a^3F_2-c^3F'_2$	87
7	5481.90	+2	5	I A	18236.80	$b^3F'_2-d^3D'_2$	88
7	5481.45	+2	6	III	18238.30	$a^3F_3-c^3F'_3$	87
2	5477.70	−2	8	III	18250.79	$a^3F_4-c^3F'_4$	87
12	5474.52	+6	(1)	(IV)	18261.27	$c^3P'_2-d^3P_1$	93
7	5474.28	+8	6	II	18262.18	$b^3F'_4-c^3G'_5$	94
12	5473.56	+5	(1)	(IV)	18264.58	$c^3P'_1-d^3P_0$	93
4	5472.73	+3	2	III A	18267.35	$b^3F'_3-c^5D'_2$	92
7	5471.19	−1	5	III	18272.50	$b^3F'_3-d^3D'_3$	88
7‡	5460.51	+3	4	I A	18308.24	$a^3F'_4-a^5D'_4$	91
7	5453.67	+2	3	III A	18331.20	$b^3F'_3-c^3G'_4$	94
2	5451.97	+2	(1)	....	18336.93	$a^3F_2-c^3F'_3$	87
7	5449.19	+4	1	III A	18346.27	$b^3F'_3-c^5D'_3$	92
12	5448.85	0	(1)	(IV)	18347.13	$c^3P'_1-d^3P_1$	93
7*	5446.67	{+1 +5}	2	II A	18354.76	{$c^3P'_0-d^3P_1$ $a^3F'_3-a^5D'_2$	93 91
7	5438.33	+2	1	III A	18382.90	$b^3F'_2-c^3G'_3$	94
7	5436.65	−4	1	III A	18388.60	$aD-b^3D'_3$	95
2	5432.32	−5	(0)	....	18403.25	$a^3F_3-c^3F'_4$	87
7	5429.15	−2	6	III	18413.99	$c^3P'_2-d^3P_2$	93
7	5426.27	+2	3	I A	18423.77	$a^3F'_3-a^5D'_3$	91
4	5419.22	−4	1	III A	18447.71	$c^3P'_2-b^5S'_2$	96
7	5409.62	−2	6	II	18480.47	$a^3G_5-d^3F_4$	97
11†	5408.93	+1	(1)	(I A)	18482.83	$a^3F'_2-a^5D'_1$	91
4	5404.03	0	2	IV	18499.58	$c^3P'_1-d^3P_2$	93
12	5401.32	−3	(1)	(III A)	18508.72	$a^5F'_2-b^3F_2$	98
4	5397.08	−2	4	III	18523.41	$a^3G_4-d^3F_3$	97
4*	5396.57	{−3 −2}	1	I A	18525.16	{$a^3F'_2-a^5D'_2$ $a^3F'_3-a^5D'_4$	91 91
7	5390.26	−2	(2)	....	18546.84	$aF'-fF$	99
7	5390.00	+3	3	III	18547.74	$a^3G_3-d^3F_2$	97
4	5389.15	−2	2	III A	18550.66	$a^5F'_1-b^3F_2$	98
12	5384.63	+1	(1)	(III A)	18566.23	$a^5F'_3-b^3F_3$	98
12†	5376.58	−1	(0)	....	18594.04	$a^3F'_2-a^5D'_3$	91

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multi-plet
7	5369.65	......	4	III	18618.02	....	......
4	5366.63	−2	2	III A	18628.51	$a^5F'_2-b^3F_3$	98
12†	5361.67	−4	(1)	(III A)	18645.75	$a^5F'_4-b^3F_4$	98
7	5351.09	+1	4	III	18682.60	$aF-bF'$	100
4	5341.48	+2	1	IV?	18716.22	$bP-bP'$	101
12	5340.68	+1	(1)	(III A)	18719.02	$a^5F'_2-b^3D'_1$	102
4	5338.28	−1	1	III A	18727.44	$a^5F'_3-b^3F_4$	98
12	5323.93	+4	(1)	(III A)	18777.91	$a^5F'_3-b^3D'_2$	102
12	5313.24	0	(2)	(III A)	18815.69	$a^3P'_2-c^3D'_2$	103
7‡	5299.98	−2	1	III A	18862.76	$a^3P'_1-c^3D'_1$	103
7	5298.42	+1	4	III	18868.32	$bD-cP$	104
7	5297.29	+4	6	III	18872.35	$a^3G_3-e^3F_2$	105
7	5295.78	0	4	III	18877.72	$a^3P'_2-c^3D'_3$	103
7	5294.75	−4	(2)	....	18881.39	$b^5F_5-f^5F'_5$	106
7	5289.28	+1	(1)	(III A)	18900.93	$a^5F'_4-b^3D'_3$	102
7	5284.39	+2	2	III A	18918.41	$a^3P'_0-c^3D'_1$	103
7	5283.45	+1	8	III	18921.78	$a^3G_4-e^3F_3$	105
7	5282.38	0	3	III A	18925.61	$a^3P'_1-c^3D'_2$	103
7	5281.93	+7	(2)	....	18927.22	$d^3D'_3-b^3D_3$	107
12	5269.93	+6	(1)	(III A)	18970.32	$a^3G_3-e^3F_3$	105
7	5266.28	0	(2)	....	18983.47	$b^5G'_5-b^5G_5$?	108
7	5265.97	0	10	III	18984.59	$a^3G_5-e^3F_4$	105
7	5263.50	−1	3	III	18993.50	$a^5F_5-b^5F'_4$	109
7	5263.32	−3	(2)	....	18994.14	$b^5G'_6-b^5G_6$	108
7	5259.97	−2	3	IV	19006.25	$aD'-bF'$	110
4	5257.58	+4	(1)	....	19014.88	$aP'-cP$	111
7	5255.82	−2	5	III	19021.25	$a^5F_4-b^5F'_3$	109
7	5252.11	+1	8	I A	19034.69	$a^3F'_4-a^3F_3$	112
12	5251.50	+1	(0)	(III A)	19036.89	$a^5F'_2-b^5D'_1$	113
4	5250.94	+1	2	III A	19038.93	$a^5F'_3-b^5D'_2$	113
11*†	5248.39	0 +2	(1)	(III A)	19048.17	$a^5F'_1-b^5D'_0$ $a^3G_4-e^3F_4$	113 105
4	5247.30	+1	5	III	19052.13	$a^5F_3-b^5F'_2$	109
7	5246.81	−1	(2)	....	19053.91	$b^5G'_4-b^5G_4$	108
4	5246.56	0	3	III A	19054.82	$a^5F'_4-b^5D'_3$	113
4	5246.14	−5	2	V	19056.34	$bD-dP$	114
12	5239.94	−1	(0)	....	19078.90	$a^5F'_1-b^5D'_1$	113
7*	5238.58	−1 +1	6	III A	19083.84	$a^5F'_5-b^5D'_4$ $a^5F_2-b^5F'_1$	113 109
12†	5233.81	−4	(1)	(III A)	19101.25	$a^5F'_2-b^5D'_2$	113
7	5227.19	+1	(2)	....	19125.43	$b^5G'_3-b^5G_3$	108
7	5224.96	0	8	III	19133.60	$a^5F_4-b^5F'_4$	109
4	5224.57	+1	6	III	19135.03	$a^5F_3-b^5F'_3$	109
7	5224.32	+1	15	III	19135.94	$a^5F_5-b^5F'_5$	109
12†	5224.13	−1	(0)	(IV A)	19136.63	$a^5F'_3-b^5D'_3$	113
7	5223.64	−1	6	III	19138.43	$a^5F_2-b^5F'_2$	109
7	5222.68	−2	6	III	19141.95	$a^5F_1-b^5F'_1$	109
7	5219.72	+1	8	I A	19152.80	$a^3F'_3-a^3F_2$	112
2	5212.27	......	3	III	19180.06	....	......
11†	5211.20	−2	(1)	(III A)	19184.10	$a^5F'_4-b^5D'_4$	113
7	5210.39	0	40	I	19187.09	$a^3F'_4-a^3F_4$	112
4	5207.87	0	3	III	19196.38	$a^5F_1-b^5F'_2$	109
7	5206.09	−4	5	III?	19202.95	$aP'-dP$	115

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
4	5201.12	0	4	III	19221.29	$a^5F_2-b^5F'_3$	109
4	5194.04	0	4	IV A	19247.49	$a^5F_3-b^5F'_4$	109
7	5192.98	+1	35	I	19251.42	$a^3F'_3-a^3F_3$	112
4	5186.32	−1	3	III	19276.15	$a^5F_4-b^5F'_5$	109
12	5183.79	−6	(1)	(III A)	19285.55	$a^3P'_2-a^5P_3$	116
12	5178.62	−9	[0]	[III A]	19304.81	$a^3P'_2-bD'$	117
7	5173.74	−1	30	I	19323.01	$a^3F'_2-a^3F_2$	112
12	5170.50	−5	(0)	....	19335.11	bG−cF	118
7	5152.18	−1	10	I A	19403.87	$a^3F'_3-a^3F_4$	112
7	5147.48	0	10	I A	19421.59	$a^3F'_2-a^3F_3$	112
7	5145.47	+1	12	II	19429.17	$b^3F'_4-e^3D'_3$	119
4	5132.96	+1	(1)	....	19476.52	$a^3H'_5-e^3G'_4$	120
11	5127.36	−2	(1)	....	19497.79	$a^3H'_6-e^3G'_5$	120
4	5124.08	+1	(1)	....	19510.28	$aG-d^3G'_5$	121
4	5122.09	−4	(1)	....	19517.86	$a^3H'_4-e^3G'_3$	120
7	5120.43	−1	12	III	19524.19	$aH'-aI'$	122
7	5113.45	+1	10	III	19550.84	$b^3F'_3-e^3D'_2$	119
4	5109.43	+1	4	III?	19566.21	$b^3F'_3-e^3D'_3$	119
7	5087.07	−1	8	III	19652.22	$b^3F'_2-e^3D'_1$	119
4	5085.35	+1	4	III	19658.87	$b^3F'_2-e^3D'_2$	119
7	5071.49	0	7	III	19712.59	$b^3F'_4-d^3G'_4$	123
11	5069.41	+10	5	IV	19720.68	$a^3D_1-d^3P_0$	124
2	5068.33	+1	3	IV	19724.87	$a^3G'_3-c^3G_3$	125
7	5066.01	+2	7	III	19733.92	$b^3F'_3-d^3G'_3$	123
7	5064.66	+2	25	I	19739.18	$a^3F'_4-a^3D'_3$	126
11	5064.07	−1	4	IV	19741.49	$a^3G'_5-c^3G_5$	125
7	5062.11	−5	7	III	19749.12	$a^3D_2-d^3P_1$	124
4*	5054.11	{+1 +1}	3	IV?	19780.38	{$a^3G'_4-c^3G_4$ aS−bP	125 127
7	5052.88	−1	8	IV?	19785.19	$a^3D_3-d^3P_2$	124
4	5048.21	−2	(1)	....	19803.50	$a^3D_1-d^3P_1$	124
7	5045.43	0	5	III A	19814.41	$a^5F'_5-b^5G'_4$	128
4	5044.25	−6	2	IV	19819.05	$a^3D_3-b^5S'_2$	129
7	5043.59	0	7	III A	19821.64	$a^5F'_4-b^5G'_3$	128
7	5040.63	+2	6	III A	19833.28	$a^5F'_3-b^5G'_2$	128
7	5039.96	+1	22	I	19835.92	$a^3F'_3-a^3D'_2$	126
7	5038.41	+1	25	II	19842.01	$b^3F'_2-d^3G'_3$	123
7	5036.47	0	25	II	19849.65	$b^3F'_3-d^3G'_4$	123
7	5035.92	+1	25	II	19851.83	$b^3F'_4-d^3G'_5$	123
7	5025.58	+1	18	III	19892.67	$a^5G'_6-b^5F'_5$	130
7	5024.85	−1	20	II	19895.56	$a^5F'_2-b^5G'_2$	128
12	5023.39	0	(2)	....	19901.35	$a^3D_2-d^3P_2$	124
7	5022.87	+1	25	II	19903.41	$a^5F'_3-b^5G'_3$	128
7	5020.04	0	25	II	19914.62	$a^5F'_4-b^5G'_4$	128
7	5016.17	0	20	II	19929.99	$a^5F'_5-b^5G'_5$	128
11*†	5014.28	+1	(25)	(I)	19937.49	{$a^5F'_1-b^5G'_2$	128
11*†	5014.19	+1	(25)	(I)	19937.83	$a^3F'_2-a^3D'_1$	126
7	5013.30	0	18	III	19941.40	$a^5G'_5-b^5F'_4$	130
7	5009.65	+2	7	I A	19955.92	$a^3F'_3-a^3D'_3$	126
2	5007.87	......	(2)	....	19963.01	....	......
7	5007.22	0	40	II	19965.61	$a^5F'_2-b^5G'_3$	128
7	5001.01	0	10	III A	19990.40	$a^5G'_4-b^5F'_3$	130
7	4999.51	0	45	II	19996.40	$a^5F'_3-b^5G'_4$	128

TABLE II—*Continued*

Source	* Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	4997.10	+ 1	8	I A	20006.05	$a^3F'_2-a^3D'_2$	126
12†	4995.08	+ 4	(1)	(III)	20014.15	$b^3P'_2-f^3D'_3$	131
7	4991.08	+ 1	50	II	20030.17	$a^5F'_4-b^5G'_5$	128
7	4989.16	+ 2	10	III	20037.89	$a^5G'_3-b^5F'_2$	130
7	4981.75	0	60	II	20067.69	$a^5F'_5-b^5G'_6$	128
7	4978.21	− 1	10	III	20081.95	$a^5G'_2-b^5F'_1$	130
7	4977.75	+ 3	5	IV	20083.81	$a^5G'_5-b^5F'_5$	130
4	4976.82	+ 2	1	IV	20087.57	$aH'-dG'$	132
7	4975.36	− 1	10	III	20093.45	$bD-dF$	133
7	4973.06	+ 2	6	III	20102.76	$a^5G'_4-b^5F'_4$	130
2	4968.57	− 1	6	III	20120.92	$a^5G'_3-b^5F'_3$	130
12	4967.30	+ 2	(1)	(III A)	20126.04	$a^3F'_2-a^3D'_3$	126
7	4964.75	0	5	III	20136.40	$a^5G'_2-b^5F'_2$	130
4‡	4958.25	+ 1	2	III A	20162.79	$aD-c^3D'_2$	134
7	4948.21	− 2	3	IV	20203.71	$a^3D_3-f^3F_3$	135
4	4948.01	+ 3	1	III A	20204.53	$a^5F'_2-c^3F_2$	136
12	4944.40	+ 1	(0)	....	20219.23	$a^5G'_2-b^5F'_3$	130
12†	4943.06	+ 2	(0)	(III A)	20224.75	$aD-c^3D'_3$	134
7	4941.58	− 4	3	IV	20230.81	$a^3D_2-f^3F_2$	135
12	4941.32	+ 3	(1)	(III A)	20231.87	$a^5F'_3-c^3F_3$	136
12	4941.01	+ 4	(1)	....	20233.15	$a^5G'_3-b^5F'_4$	130
7	4938.31	+ 2	8	IV	20244.21	$aH'-bH$	137
12	4938.04	+ 1	(0n)	....	20245.31	$a^5G'_4-b^5F'_5$	130
7	4937.75	+ 3	4	III A	20246.50	$a^5F'_1-c^3F_2$	136
12	4928.89	+ 1	(0)	....	20282.82	$a^5F'_4-c^3F_4$	136
7	4928.36	+ 2	12	III	20285.09	$a^3D_1-f^3F_2$	135
7	4926.17	+ 2	4	III A	20294.10	$a^5F'_2-c^3F_3$	136
7	4925.42	− 1	5	IV	20297.19	$a^3G_4-b^3H_4$	138
7	4921.79	− 1	12	III	20312.16	$a^3D_3-f^3F_4$	135
7	4919.88	− 5	10	III	20320.05	$a^3D_2-f^3F_3$	135
7	4915.24	− 1	5	III	20339.23	$a^3G_5-b^3H_5$	138
7	4913.63	0	20	III	20345.89	$a^3G_3-b^3H_4$	138
4	4909.11	+ 1	2	III A	20364.62	$a^5F'_3-c^3F_4$	136
11†	4908.49	+ 4	(0)	....	20367.20	$a^3G'_5-e^3F'_4$	139
11†	4900.63	+ 2	(0)	....	20399.85	$a^3G'_4-e^3F'_3$	139
7	4899.93	0	20	III	20402.77	$a^3G_4-b^3H_5$	138
12	4893.90	− 2	(1)	....	20427.89	$a^3D_2-f^3D'_1$	140
7	4893.06	− 1	2	IV	20431.42	$a^3H'_5-a^3I'_5$	141
4	4891.85	− 1	1	IV	20436.48	$a^3D_3-f^3D'_2$	140
7	4885.09	0	20	II	20464.75	$a^3G_5-b^3H_6$	138
7	4882.34	+ 2	2	IV	20476.28	$a^3H'_6-a^3I'_6$	141
7	4880.92	+ 2	3	IV	20482.25	$a^3D_1-f^3D'_1$	140
7	4870.14	+ 2	20	III	20527.58	$a^3H'_5-a^3I'_6$	141
7	4868.28	− 1	18	III	20535.42	$a^3H'_4-a^3I'_5$	141
4	4864.22	+ 3	4	III	20552.56	$a^3D_2-f^3D'_2$	140
7	4856.01	0	20	III	20587.31	$a^3H'_6-a^3I'_7$	141
7	4848.46	0	8	IV	20619.36	$a^3D_3-f^3D'_3$	140
7	4843.99	0	2	IV	20638.39	$b^3P'_1-g^3D'_2$	142
7	4840.88	− 1	25	I	20651.65	$aD-bD'$	143
12	4839.23	− 6	(1)	....	20658.74	$b^3P'_0-g^3D'_1$	142
7	4836.13	0	6	III	20671.93	$bG-cG'$	144
4	4832.09	+ 2	(1)	....	20689.21	$a^5D'_2-c^5F'_3$	145
7	4827.60	− 2	2	IV?	20708.46	$a^5D'_3-c^5F'_4$	145

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
11	4825.49	+1	3	IV	20717.51	$a^5D'_4-c^5F'_5$	145
12	4821.29	−3	(1bd?)	....	20735.46	$a^3D_2-f^3D'_3$	140
7	4820.42	0	20	II	20739.30	aG−bF	146
11†	4812.89	0	(0)	(III A)	20771.71	$a^5F'_5-b^3G'_4$	147
7	4812.25	+1	5	III	20774.51	$c^3P'_2-h^3D'_2$	148
7	4811.09	+6	4	IV	20779.52	a^3G_5-bG'	149
7	4808.54	0	5	IV	20790.54	aG′−bH′	150
7	4805.43	−1	12	III	20804.00	$c^3P'_2-h^3D'_3$	148
7	4799.81	0	12	III	20828.35	$bG-c^3H_4$	151
7	4797.99	0	5	III	20836.26	$c^3P'_1-h^3D'_1$	148
7	4796.22	−1	6	III	20843.94	$c^3P'_0-h^3D'_1$	148
7	4792.50	+2	10	III	20860.13	$c^3P'_1-h^3D'_2$	148
6	4789.79	+1	(1−)	....	20871.90	$a^5F'_4-b^3G'_4$	147
12	4783.31	0	[2]	[III A]	20900.09	$a^5F'_2-b^3G'_3$	147
7	4781.73	+1	6	III A	20907.11	$a^5F'_5-b^3G'_5$	147
7	4778.27	0	10	III	20922.25	$a^3H'_4-cG'$	152
4	4771.13	+3	3	III A	20953.56	$a^5F'_3-b^3G'_4$	147
7	4769.78	0	4	III	20959.49	$a^3H'_6-c^3H_5$	153
7	4766.33	−1	4	III	20974.65	$a^3H'_5-c^3H_4$	153
12	4759.74	+8	(1bd?)	....	21003.71	$a^3D_3-g^3F_3$	154
7	4759.28	0	25	III	21005.73	$a^3H'_6-c^3H_6$	153
7	4758.92	+1	4	III A	21007.32	$a^5F'_4-b^3G'_5$	147
7	4758.13	−1	25	III	21010.81	$a^3H'_5-c^3H_5$	153
12	4754.38	−3	(1bd?)	....	21027.32	$a^3D_2-g^3F_2$	154
7	4747.69	0	3	III	21057.01	$a^3H'_5-c^3H_6$	153
4	4747.29	+1	1	III A	21058.78	$a^3P'_2-d^3D'_1$	155
7	4742.80	0	20	III	21078.72	$a^3H'_4-c^3H_4$	153
7	4742.13	0	3	IV	21081.69	$a^3D_1-g^3F_2$	154
7	4734.68	0	3	IV?	21114.87	$a^3H'_4-c^3H_5$	153
7	4733.43	−4	6	III?	21120.44	$a^3D_2-g^3F_3$	154
7	4731.18	−2	9	III	21130.48	$a^3D_3-g^3F_4$	154
12	4724.68	+2	(2)	....	21159.53	$a^3D_3-g^3D'_2$	156
7	4723.18	0	10	III	21166.27	$a^3P'_2-d^3D'_2$	155
7	4722.63	+1	10	III	21168.74	$a^3P'_1-d^3D'_1$	155
7	4715.31	−1	4	II A	21201.61	$a^3F'_4-a^3G'_4$	157
7*	4710.19	−2 0	18	III	21224.64	$a^3P'_0-d^3D'_1$ $a^3D_3-g^3D'_3$	155 156
11	4708.97	−1	1	IV?	21230.15	$a^3D_2-g^3D'_1$	156
12*†	4698.82	−4	(6?)	....	21276.00	$a^3D_2-g^3D'_2$	156
7*	4698.79	+2	20	II	21276.14	$a^3P'_1-d^3D'_2$	155
7	4696.92	0	4	IV?	21284.62	$a^3D_1-g^3D'_1$	156
7	4693.68	+2	5	II A	21299.30	$a^3F'_3-a^3G'_3$	157
7	4691.34	0	20	II	21309.93	$a^3P'_2-d^3D'_3$	155
7	4690.81	+1	3	IV?	21312.34	$a^3P'_2-c^3G'_3$	158
4	4688.38	+1	3	IV?	21323.38	$a^3S'_1-d^3P'_2$	159
4	4686.92	0	4	IV?	21330.02	$a^3D_1-g^3D'_2$	156
4	4684.53	−1	2	IV?	21340.90	$a^3D_2-g^3D'_3$	156
7	4681.91	−1	30	I	21352.85	$a^3F'_4-a^3G'_5$	157
11	4677.42	−3	2	IV?	21373.35	aG′−cG	160
11	4676.92	−1	1	IV?	21375.64	bD−eF	161
7	4675.13	0	10	III	21383.82	$a^3P'_2-c^5D'_3$	162
4	4668.38	+2	2	IV?	21414.74	$a^3P'_1-c^5D'_2$	162
7	4667.59	−1	25	I	21418.36	$a^3F'_3-a^3G'_4$	157

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	4656.47	+1	25	I	21469.50	$a^3F'_2-a^3G'_3$	157
7	4656.06	+2	6	III	21471.39	$a^5P'_3-d^5D'_2$	163
7	4655.70	−1	3	IV?	21473.06	$c^3P'_2-e^3P_1$	164
7	4650.02	0	10	III	21499.29	$a^5P'_2-d^5D'_1$	163
7	4645.19	0	12	III	21521.65	$a^5P'_1-d^5D'_0$	163
4	4640.37	−3	2	IV?	21543.99	$c^3P'_1-e^3P_0$	164
7	4639.94	0	15	III	21545.99	$a^5P'_1-d^5D'_1$	163
7	4639.66	0	15	III	21547.29	$a^5P'_3-d^5D'_3$	163
7	4639.36	0	18	III	21548.68	$a^5P'_2-d^5D'_2$	163
7	4637.88	−2	8	IV?	21555.57	$c^3P'_2-e^3P_2$	164
8	4637.24	+3	2	IV?	21558.57	$c^3P'_1-e^3P_1$	164
7	4635.55	−1	3	IV?	21566.39	$c^3P'_0-e^3P_1$	164
7	4629.34	+1	15	III	21595.33	$a^5P'_1-d^5D'_2$	163
7	4623.10	0	25	III	21624.48	$a^5P'_2-d^5D'_3$	163
4	4619.53	−1	3	IV?	21641.19	$c^3P'_1-e^3P_2$	164
7	4617.27	+1	30	II	21651.78	$a^5P'_3-d^5D'_4$	163
7	4614.29	−1	1	V	21665.77	a^3F_3-bF'	165
7	4599.23	......	5	IV	21736.71	....	......
11†	4576.52	+3	(0)	....	21844.57	$c^3P'_1-i^3D'_2$	166
7	4570.91	+1	3n	III	21871.38	$a^3F_2-c^3G_3$	167
7	4564.23	+1	1	III A	21903.39	$b^3F'_4-d^3F_3$	168
7	4563.44	0	5	III	21907.18	$a^3F_4-c^3G_5$	167
7	4562.63	−1	6	II A	21911.07	$a^3F'_3-aD'$	169
7	4559.94	0	6	III	21923.99	$b^3F'_4-d^3F_4$	168
7*	4558.12	{−2 −2}	2	IV	21932.75	{$c^3P'_2-i^3D'_3$ $c^3P'_2-c^3S'_1$	166 170
4	4557.85	−1	2	IV	21934.05	$a^3D'_1-e^3F'_2$	171
7	4555.50	+1	30	II	21945.36	$a^5F'_5-b^5F_4$	172
7	4555.10	−1	3	III	21947.29	$a^3F_3-c^3G_4$	167
4	4553.41	0	(1)	....	21955.43	$aG'-cF'$	173
2	4552.45	−3	35	II	21960.07	$a^5F'_4-b^5F_3$	172
7	4548.77	0	35	II	21977.83	$a^5F'_3-b^5F_2$	172
4	4548.12	−1	2	III	21980.97	$a^3D'_3-e^3F'_4$	171
4	4547.86	+2	2	III	21982.23	$a^3D'_2-e^3F'_3$	171
7	4544.70	+2	30	II	21997.51	$a^5F'_2-b^5F_1$	172
4	4541.00	0	(1)	....	22015.43	$bG-dF$	174
7	4540.87	+1	1	III A	22016.06	$b^3F'_3-d^3F_2$	168
4	4540.48	−3	1	III A	22017.95	$a^3F'_4-aF$	175
2	4539.10	......	3	IV	22024.66	....	......
7	4536.00	−2	40	II	22039.71	$a^5F'_1-b^5F_1$	172
7	4535.92	−2	40	II	22040.10	$a^5F'_2-b^5F_2$	172
7	4535.58	−1	50	II	22041.75	$a^5F'_3-b^5F_3$	172
7	4534.78	−1	60	II	22045.63	$a^5F'_4-b^5F_4$	172
7	4533.25	0	80	II	22053.07	$a^5F'_5-b^5F_5$	172
11	4527.46	0	(4)	(III A?)	22081.17	$a^3F'_2-aD'$	169
7	4527.32	0	35	II	22081.95	$a^5F'_1-b^5F_2$	172
4*	4526.36	{0 −1}	1	III A	22086.63	{$a^5F_5-c^5F'_4$ $aG-e^3F_4$	176 177
7‡	4522.80	−4	40	II	22104.07	$a^5F'_2-b^5F_3$	172
7	4518.69	0	8	III	22124.13	$b^3F'_2-d^3F_2$	168
7	4518.03	+1	50	II	22127.36	$a^5F'_3-b^5F_4$	172
2	4515.61	−3	1	IV A	22139.22	$a^5F_4-c^5F'_3$	176
4	4513.71	−1	1	IV A	22148.53	$b^3F'_2-d^3F_3$	168

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	4512.74	0	40	II	22153.30	$a^5F'_4-b^5F_5$	172
7	4511.18	......	3	IV	22160.96	....	......
7	4508.28	−1	1	IV	22175.22	$a^3D_3-h^3D'_3$	178
7	4508.04	+1	2	IV	22176.40	$aF-cD$	179
12	4507.64	+1	[00]	....	22178.38	$a^3H'_5-aI'$	180
4	4505.71	0	1	IV	22187.86	$a^5F_3-c^5F'_2$	176
7	4503.78	−1	4n	IV	22197.37	$a^5F_5-c^5F'_5$	176
7	4497.75	−2	3	III	22227.13	$a^5F_4-c^5F'_4$	176
8	4496.24	−1	2	III A	22234.59	$a^3F'_3-aF$	175
7	4496.15	−1	20	III	22235.04	$a^5P'_3-b^5P_2$	181
7	4495.02	......	4	III	22240.63	....	......
7	4492.56	+3	3	III	22252.80	$a^5F_3-c^5F'_3$	176
12	4490.69	0	(2)	....	22261.98	$a^3D_2-h^3D'_2$	178
7	4489.10	0	20	III	22269.96	$a^5P'_2-b^5P_1$	181
2	4485.01	−4	1	IV A	22290.24	$a^5F_1-c^5F'_1$	176
12	4484.53	−2	(2)	....	22292.66	$a^3D_1-h^3D'_1$	178
7	4482.69	−1	10	III	22301.80	$b^3F'_4-e^3F_3$	182
7	4481.27	+1	30	III	22308.87	$a^5P'_3-b^5P_3$	181
7	4480.61	+1	5	III A	22312.15	$a^5P'_2-b^5P_2$	181
7	4479.70	0	9	III	22316.68	$a^5P'_1-b^5P_1$	181
4	4475.51	−2	1	IV	22337.58	$a^5F_4-c^5F'_5$	176
7*	4474.86	−1 +2	8	III	22340.83	$b^3F'_3-e^3F_2$ $a^5F_3-c^5F'_4$	182 176
7	4471.24	0	20	III	22358.91	$a^5P'_1-b^5P_2$	181
7	4465.80	−1	20	III	22386.15	$a^5P'_2-b^5P_3$	181
7	4463.55	+1	8	III	22397.43	$a^3G_5-e^3G'_4$	183
7	4463.39	−1	8	III	22398.23	$a^3G_4-e^3G'_3$	183
7	4462.08	−2	(3)	(III A)	22404.81	$a^3F'_2-aF$	175
7	4457.42	−1	40	II	22428.23	$b^3F'_4-e^3F_4$	182
7	4455.32	0	30	II	22438.80	$b^3F'_3-e^3F_3$	182
7	4453.70	−2	20	III	22446.97	$a^3G_3-e^3G'_3$	183
7	4453.32	−1	30	II	22448.87	$b^3F'_2-e^3F_2$	182
7	4450.90	0	25	III	22461.09	$a^3G_4-e^3G'_4$	183
7	4449.99	+2	1	IV	22465.68	a^3G_4-cF	184
7	4449.13	−2	30	III	22470.02	$a^3G_5-e^3G'_5$	183
2	4444.27	−2	(1)	....	22494.61	$b^3P'_1-i^3D'_1$	185
7	4443.20	0	(3)	....	22500.01	$aD'-cD$	186
7	4441.26	−1	4	IV	22509.84	$a^3G_3-e^3G'_4$	183
7	4440.34	0	10	III	22514.50	a^3G_3-cF	184
7	4438.23	0	2	IV	22525.21	$b^3P'_2-i^3D'_2$	185
12	4436.64	−3	(1)	(III?)	22533.23	$a^3F_4-e^3F'_4$	187
7	4436.59	0	4	III	22533.53	$a^3G_4-e^3G'_5$	183
7*	4433.99	+2 −2	15	III A	22546.74	$b^3F'_2-e^3F_3$ $a^3G_3-f^3F_2$	182 188
7	4433.58	+1	3	III	22548.83	$a^3F_2-e^3F'_2$	187
7	4431.28	−4	4	III	22560.53	$b^3P'_0-i^3D'_1$	185
7	4430.37	+1	7	III A	22565.17	$b^3F'_3-e^3F_4$	182
7	4430.03	−2	3	III	22566.90	$a^3F_3-e^3F'_3$	187
7	4427.10	0	40	III	22581.83	$aG-aH$	189
7	4426.05	−1	10	II?	22587.18	$a^3G_4-f^3F_3$	188
7	4425.83	0	3	III A	22588.31	$a^3P'_2-e^3D'_2$	190
7	4424.40	+1	2	III	22595.62	$bG-dG'$	191
7	4422.82	−1	10	II	22603.69	$a^3P'_2-e^3D'_3$	190

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	4421.75	−2	6	III	22609.16	$b^3P'_1-i^3D'_2$	185
7	4421.47	+2	1	IV	22610.60	$a^3F_4-b^5D_4$	192
12	4417.43	−3	(1n)	....	22631.27	$a^3F_3-b^5D_3$	192
7	4417.28	−1	15	III	22632.04	$a^3G_5-f^3F_4$	188
7	4416.54	0	4	III?	22635.83	$a^3G_3-f^3F_3$	188
7	4412.43	+3	1	III A	22656.90	$aD-d^3D'_3$	193
7	4405.70	0	2	III A	22691.52	$a^3P'_1-e^3D'_1$	190
4‡	4404.91	+1	5	III	22695.59	$a^3G_4-f^3F_4$	188
4	4404.40	+1	5	III A	22698.21	$a^3P'_1-e^3D'_2$	190
7*	4404.27	−2	10	III	22698.89	$b^3P'_2-c^3S'_1$ $b^3P'_2-i^3D'_3$	194 185
7	4400.60	+2	(2)	....	22717.82	$bD-eP$	195
12	4394.85	−4	(2)	(III A)	22747.54	$a^3P'_0-e^3D'_1$	190
7	4393.93	0	8	III	22752.30	$bG-bH$	196
7	4388.09	+1	3	III	22782.58	$b^3P'_1-c^3S'_1$	194
7	4375.44	+2	1	IV	22848.44	$b^3P'_0-c^3S'_1$	194
7	4372.40	+4	3	IV	22864.34	$aP'-eP$	197
7	4369.70	+4	5n	IV	22878.46	$aH'-eG'$	198
7	4368.97	−2	2	IV	22882.28	$bG-f^3G'_3$	199
7	4361.15	+2	1	IV	22923.31	$b^3F'_4-aH$	200
7	4360.51	+1	4	III?	22926.68	$a^3D_3-e^3P_2$	201
7	4355.32	+1	1	IV A	22954.00	$a^5G'_6-c^5F'_5$	202
7	4354.08	−1	3	III	22960.54	$a^3D_2-e^3P_1$	201
7	4346.60	+2	1	IV	23000.05	$a^3D_1-e^3P_0$	201
7	4346.13	+2	5	IV	23002.53	$a^3H'_4-bH$	203
4	4343.80	+2	1	IV	23014.87	$a^3D_1-e^3P_1$	201
7	4340.06	+3	1	IV?	23034.71	$a^5G'_5-c^5F'_4$	202
7	4338.50	−1	1	IV?	23042.99	$a^3D_2-e^3P_2$	201
7	4334.86	+2	2	III A	23062.33	$a^5F'_2-d^3D'_1$	204
7	4326.98	+1	2	III A	23104.34	$a^5F'_1-d^3D'_1$	204
7	4326.35	0	9	II	23107.70	$a^5F'_3-d^3D'_2$	204
7	4325.13	−3	9n	III	23114.21	$a^3H'_5-f^3G'_4$	205
7	4323.44	+1	1	III A	23123.25	$a^3P'_2-b^3P_1$	206
7	4321.70	−1	8n	III	23132.58	$a^3H'_4-f^3G'_3$	205
7	4318.64	0	10n	III	23148.95	$a^3H'_6-f^3G'_5$	205
7*	4314.80	0 +6	25	II	23169.55	$a^5F'_4-d^3D'_3$ $a^5F'_2-d^3D'_2$	204 204
7	4314.34	−1	5	III A	23172.03	$a^5F'_4-c^3G'_3$	207
7	4311.65	0	2	IV	23186.47	$a^3D_1-i^3D'_1$	208
7	4310.36	0	1	III A	23193.42	$a^3P'_1-b^3P_0$	206
7	4309.09	0	1	IV	23200.25	$a^3H'_5-f^3G'_5$	205
4	4308.47	−1	2	III A	23203.60	$a^3P'_2-b^3P_2$	206
4	4306.92	−2	1	III A	23211.94	$a^5F'_1-d^3D'_2$	204
7	4305.91	−1	60	II	23217.39	$a^5F'_5-c^5D'_4$	209
4	4305.43	−3	2	III A	23219.97	$a^5P'_3-d^3P_2$	210
4	4302.97	0	1n	III A	23233.25	$a^3P'_1-b^3P_1$	206
7	4301.08	0	50	II	23243.46	$a^5F'_4-c^5D'_3$	209
7	4300.55	−1	50	II	23246.32	$a^5F'_3-c^5D'_2$	209
7	4299.64	+2	15	III	23251.24	$a^5F'_3-d^3D'_3$	204
7‡	4299.24	+1	15	III	23253.39	$a^5P'_3-b^5S'_2$	211
7	4298.67	−1	40	II	23256.49	$a^5F'_2-c^5D'_1$	209
7	4295.75	0	22	II	23272.30	$a^5F'_1-c^5D'_0$	209
4	4292.64	−2	1	III A	23289.16	$a^3P'_0-b^3P_1$	206

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multi-plet
4........	4291.88	− 2	(1)	....	23293.28	$a^5D_4'-e^3F_3'$	212
2*........	4291.21	+ 1 − 7	5n	IV	23296.92	$a^5P_2'-d^3P_2$ $a^5F_4'-c^3G_5'$	210 207
7........	4290.93	− 1	22	II	23298.44	$a^5F_1'-c^5D_1'$	209
7........	4289.92	− 1	3	III	23303.92	$a^3D_3-i^3D_3'$	208
7........	4289.08	− 1	25	II	23308.50	$a^5F_2'-c^5D_2'$	209
7*........	4288.18	+ 1 + 2	3	III A	23313.38	$a^3P_1'-b^3P_2$ $a^5F_2'-d^3D_3'$	206 204
7........	4287.41	0	22	II	23317.57	$a^5F_4'-c^5D_4'$	209
7........	4286.01	+ 1	25	II	23325.19	$a^5F_3'-c^5D_3'$	209
7........	4284.99	− 1	8	III	23330.73	$a^5P_2'-b^5S_2'$	211
7........	4282.72	+ 1	12	III	23343.10	$a^3G_3-g^3F_2$	213
7‡........	4281.40	+ 2	10	III	23350.30	$a^5F_1'-c^5D_2'$	209
7........	4280.08	0	2n	III	23357.50	$a^5D_4'-b^5D_3$	214
7........	4278.81	+ 1	3n	III	23364.44	$a^5D_3'-b^5D_2$	214
7‡........	4278.23	0	7	IV	23367.60	$aH'-cH$	215
7........	4276.66	0	2	III	23376.18	$a^5D_2'-b^5D_1$	214
7........	4276.44	0	8	III	23377.38	$a^5P_1'-b^5S_2'$	211
7*........	4274.60	+ 2 − 1	15	III	23387.44	$a^3G_4-g^3F_3$ $a^5F_2'-c^5D_3'$	213 209
2........	4274.41	+ 4	(1n)	(III)	23388.50	$a^5D_1'-b^5D_0$	214
7........	4273.31	− 2	2	IV	23394.50	$a^5D_3'-e^3F_3'$	212
7........	4272.44	+ 1	8	III A	23399.27	$a^5F_3'-c^5D_4'$	209
7........	4270.14	− 1	7n	IV	23411.86	$a^5D_4'-e^3F_4'$	212
12........	4268.92	− 1	(1n)	(III)	23418.55	$a^5D_1'-b^5D_1$	214
7........	4266.21	0	3n	IV	23433.44	$a^5D_2'-b^5D_2$	214
7........	4265.71	+ 1	4	IV	23436.19	$a^3G_3-g^3F_3$	213
4........	4265.28	0	3n	III	23438.55	$a^5D_0'-b^5D_1$	214
7........	4263.14	− 1	15	III	23450.31	$a^3G_5-g^3F_4$	213
7........	4261.61	0	5n	III	23458.73	$a^5D_3'-b^5D_3$	214
2........	4260.74	− 4	2	IV	23463.52	$a^5D_2'-e^3F_3'$	212
7........	4258.53	− 1	4n	IV	23475.70	$a^5D_1'-b^5D_2$	214
7........	4256.04	+ 1	8n	III	23489.43	$a^5D_4'-b^5D_4$	214
7........	4251.76	0	2n	III	23513.07	$a^5D_3'-e^3F_4'$	212
7........	4251.60	− 1	3	III	23513.96	$a^3G_4-g^3F_4$	213
7........	4249.13	0	5n	III	23527.63	$a^5D_2'-b^5D_3$	214
7........	4237.88	− 3	7	III	23590.09	$bD-eD'$	216
2........	4237.79	+ 1	(2)	(III)	23590.62	$a^5D_3'-b^5D_4$	214
7........	4227.64	+ 1	5	III	23647.22	$aP'-dD'$	217
7........	4224.78	+ 2	5	IV	23663.23	$aF-cG$	218
7........	4211.72	0	4	III	23736.61	$aP'-eD'$	219
11........	4203.46	− 1	8	IV	23783.25	$b^3P_2'-f^3P_2$	220
7........	4200.79	+ 3	6	III	23798.37	$b^3P_2'-f^3P_1$	220
7........	4188.69	− 1	5	III	23867.12	$b^3P_1'-f^3P_2$	220
7‡........	4186.12	+ 1	25	III	23881.76	$aG-bG'$	221
7........	4183.29	0	4	III	23897.92	$b^3P_1'-f^3P_0$	220
7........	4180.86	− 7	(3)	....	23911.80	$aS-cP$	222
4........	4180.52	− 7	(1)	....	23913.74	$a^3D_2-h^3F_2$	223
4........	4179.91	+ 1	(1)	....	23917.24	$a^3D_3-h^3F_3$	223
12........	4177.36	− 4	(2)	....	23931.88	$a^3G_5-c^3H_5$	224
7........	4174.47	− 4	3	III	23948.40	$b^3P_0'-f^3P_1$	220
2§........	4174.09	− 2	(1)	(III A)	23950.93	$aD-e^3D_3'$	225
12........	4172.54	+ 4	(2)	....	23958.94	$a^3G_4-c^3H_4$	224

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	4171.02	− 7	8	III	23968.26	$a^3D_1-h^3F_2$	223
7	4169.33	0	7	III	23977.93	$a^3G_5-c^3H_6$	224
4	4166.32	+ 1	6	III	23995.26	$a^3G_4-c^3H_5$	224
4	4164.14	+ 1	4	III	24007.82	$a^3G_3-c^3H_4$	224
4	4159.64	− 5	9	III?	24033.79	$a^3D_2-h^3F_3$	223
7	4150.97	− 3	10	III	24083.98	$a^3D_3-h^3F_4$	223
7	4150.54	0	3	III	24086.49	$a^5D'_2-b^5P'_1$	226
2	4149.45	− 1	(1)	....	24092.84	$a^3G'_5-b^3H'_5$	227
2	4148.39	+ 4	(1)	....	24098.97	$aS-dP$	228
4	4145.03	+ 1	(1)	....	24118.50	$aD-d^3G'_3$	229
7	4143.28	+ 1	3	III	24128.68	$a^5D'_1-b^5P'_1$	226
7	4143.04	+ 1	7n	III	24130.09	$a^5D'_3-b^5P'_2$	226
2	4142.48	+ 2	2	IV	24133.34	$a^3G'_4-b^3H'_4$	227
4‡	4139.83	− 1	2	IV	24148.80	$a^5D'_0-b^5P'_1$	226
7	4137.29	+ 1	10n	III	24163.62	$a^5D'_4-b^5P'_3$	226
7	4131.26	+ 2	4	III	24198.90	$a^5D'_2-b^5P'_2$	226
2	4129.17	......	4	III	24211.15	....	......
7	4127.54	0	15	III	24220.70	$a^3G'_5-b^3H'_6$	227
12	4124.00	− 3	(1n)	(V)	24241.42	$a^5D'_1-b^5P'_2$	226
7‡	4123.57	+ 1	10	III?	24244.05	$a^3G'_4-b^3H'_5$	227
7	4123.31	+ 1	5n	IV	24245.54	$aF-cF'$	230
2	4122.14	− 1	10	III	24252.40	$a^3G'_3-b^3H'_4$	227
7	4121.64	......	4	III	24255.37	....	......
4	4120.01	− 1	2	III	24264.96	$a^5D'_3-b^5P'_3$	226
7	4112.73	0	20	II	24307.92	$a^3F'_4-aG'$	231
7	4099.17	− 1	8	III	24388.32	$a^3D_3-f^3P_2$	232
7	4082.46	0	20	III	24488.15	$a^3P'_2-c^3P_1$	233
7	4079.73	− 1	6	III	24504.53	$a^3D_2-f^3P_2$	232
7	4078.47	− 1	30	III	24512.10	$a^3P'_2-c^3P_2$	233
7	4077.15	− 3	4	IV	24520.04	$a^3D_2-f^3P_1$	232
4	4076.38	0	4	III A	24524.67	$a^3F'_3-aG'$	231
5	4074.36	− 1	3	IV	24536.84	$a^5D'_4-d^5F'_4$	234
7	4071.48	− 1	2	IV	24554.19	$a^5D'_3-d^5F'_3$	234
4	4071.26	− 1	2	IV	24555.51	$a^5D'_2-d^5F'_2$	234
7	4069.00	− 1	4n	IV	24569.15	$aD'-cF'$	235
4	4068.65	0	(1)	....	24571.27	$a^5D'_0-d^5F'_1$	234
7	4068.14	0	3	IV	24574.34	$a^3D_1-f^3P_1$	232
12	4065.57	0	(0)	....	24589.88	$a^3D_1-f^3P_0$	232
7	4065.11	0	15	III	24592.66	$a^3P'_1-c^3P_0$	233
7	4064.22	0	15	III	24598.05	$a^3P'_1-c^3P_1$	233
7	4060.27	+ 1	20	III	24621.97	$a^3P'_1-c^3P_2$	233
7	4058.15	0	7	IV	24634.84	$a^5D'_4-d^5F'_5$	234
7	4057.64	+ 1	5	III	24637.93	$a^5D'_3-d^5F'_4$	234
7	4055.02	0	20	III	24653.86	$a^3P'_0-c^3P_1$	233
7	4052.95	+ 2	2	III	24666.44	$a^3D_3-j^3D'_2$	236
7	4049.39	− 1	2n	III	24688.13	$a^5F_5-a^5G_5$	237
7	4043.77	− 2	2	IV	24722.43	$a^3D_2-j^3D'_1$	236
7	4040.33	− 2	4n	III	24743.50	$a^5F_4-a^5G_4$	237
7	4035.84	− 1	10	III	24771.02	$a^3D_3-j^3D'_3$	236
7	4034.92	+ 2	5	III	24776.66	$a^3D_1-j^3D'_1$	236
7	4033.92	0	6	III	24782.80	$a^3D_2-j^3D'_2$	236
2	4032.63	0	3n	V	24790.75	$a^3G'_5-f^3F'_4$	238
7	4031.77	0	3n	III	24796.03	$a^5F_3-a^5G_3$	237

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	4030.53	+2	25n	III	24803.65	$a^5F_5-a^5G_6$	237
2	4027.43	......	4	IV	24822.77	......	......
7	4026.54	−1	25n	III	24828.22	$a^5F_4-a^5G_5$	237
7	4024.57	0	35	II	24840.37	$a^3F'_4-b^3F_3$	239
4	4021.87	+4	25n	III	24857.06	$a^5F_3-a^5G_4$	237
7	4017.78	−1	15n	III	24882.35	$a^5F_2-a^5G_3$	237
7	4016.99	−1	3	III	24887.25	$a^3D_2-j^3D'_3$	236
7	4016.30	+1	6	III	24891.53	$a^5F_5-e^3F'_4$	240
7	4015.40	+1	12n	III	24897.11	$a^5F_1-a^5G_2$	237
7	4013.60	+1	12n	III	24908.27	$a^5F_5-a^5H'_6$	241
7	4012.81	−1	3	III	24913.17	$a^5F_4-e^3F'_3$	240
12	4011.55	+3	[3]	[III A]	24921.01	$a^3F'_2-a^3S'_1$	242
7	4009.68	+2	15	II	24932.63	$a^3F'_3-a^5S'_2$	243
7‡	4008.94	+1	35	II	24937.23	$a^3F'_3-b^3F_2$	239
7	4008.07	+1	9n	III	24942.63	$a^5F_4-a^5H'_5$	241
7	4007.21	0	3n	IV	24947.99	$a^5F_2-a^5H'_3$	241
7	4005.98	0	6n	III	24955.65	$a^5F_3-a^5H'_4$	241
4	4003.80	0	10n	III	24969.24	$a^5F_5-b^5D_4$	244
7	4002.50	+1	9n	III	24977.34	$a^5F_4-b^5D_3$	244
7‡	3999.34	0	7n	III	24997.11	$a^5F_3-b^5D_2$	244
7	3998.65	+2	100R	II	25001.40	$a^3F'_4-b^3F_4$	239
7*	3994.70	+14 +1	4n	III	25026.12	$a^5F_3-e^3F'_3$ $a^5F_2-b^5D_1$	240 244
4	3993.79	−1	1	IV	25031.83	$a^5F_4-e^3F'_4$	240
12	3990.18	−2	(1n)	(III)	25054.47	$a^5F_1-b^5D_0$	244
7	3989.77	+1	80r	II	25057.04	$a^3F'_3-b^3F_3$	239
2	3989.58	0	(1)	(III A)	25058.28	$a^3P'_2-aP$	245
2	3985.43	......	3	III	25084.25	......	......
2	3985.25	......	3	III	25085.49	......	......
7	3984.33	+1	3	III	25091.25	$a^5F_3-b^5D_3$	244
7	3982.54	+6	30	II	25102.53	$a^3F'_2-a^5S'_2$	243
7	3981.77	+1	70r	II	25107.38	$a^3F'_2-b^3F_2$	239
2	3981.47	+1	(1)	(III)	25109.27	$a^5F_4-b^5D_4$	244
12	3972.10	−4	(0)	(III A)	25168.52	$a^3P'_1-aP$	245
7	3964.27	+1	35	II	25218.21	$a^3F'_3-b^3F_4$	239
12	3963.33	+3	(0)	(III A)	25223.87	$a^3P'_0-aP$	245
7	3962.85	0	35	II	25227.26	$a^3F'_2-b^3F_3$	239
7	3958.21	+1	80	II	25256.83	$a^3F'_4-b^3D'_3$	246
7	3956.28	−4	60	II	25269.14	$a^3F'_3-b^3D'_2$	246
7	3948.66	0	60	II	25317.91	$a^3F'_2-b^3D'_1$	246
7	3947.75	−2	40	II	25323.75	$a^3F'_3-a^3P_2$	247
4	3937.97	+1	2n	IV	25386.63	$bG-eG'$	248
7	3934.23	−1	9	III	25410.76	$a^3F'_4-b^5D'_3$	249
7	3929.87	+1	40	II	25438.95	$a^3F'_2-b^3D'_2$	246
9	3928.18	−3	(0)	......	25449.90	$a^3G'_4-g^3F'_3$?	250
12	3927.40	−1	(2)	......	25455.07	$a^3G'_5-g^3F'_4$	250
7	3926.32	+1	10	IV	25461.95	$aH'-fG'$	251
7	3924.51	−1	50	II	25473.69	$a^3F'_3-b^3D'_3$	246
7	3921.42	0	30	II	25493.77	$a^3F'_2-a^3P_2$	247
7	3919.82	0	5	III	25504.17	$aG-cF$	252
2	3916.11	......	3	IV	25528.37	......	......
7	3915.88	0	3	III A	25529.83	$a^3F'_3-b^5D'_2$	249
7	3914.72	0	5	III	25537.40	$a^3F'_2-a^3P_1$	247

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	3914.33	0	35	II	25539.94	$a^3F'_4-b^5D'_4$	249
7	3912.58	−3	2	IV	25551.38	$a^5G'_5-a^5G_4$	253
12	3911.37	0	(2)	(IV)	25559.27	$a^5G'_6-a^5H'_5$	254
7	3911.18	0	8n	III	25560.51	$a^5G'_6-a^5G_6$	253
7	3904.77	0	40n	II	25602.47	$aD-bF$	255
7	3900.96	0	12	II	25627.47	$a^3F'_3-b^5D'_3$	249
2*	3899.67	−3 0	(2)	......	25635.97	$a^3F'_2-b^5D'_1$ $a^5G'_5-a^5G_5$	249 253
7	3898.49	+1	8	III	25643.72	$a^3F'_2-b^3D'_3$	246
7	3897.58	−2	1	IV	25649.70	$a^5G'_5-a^5H'_4$	254
7	3897.32	0	1	IV	25651.40	$a^5G'_4-a^5G_3$	253
7	3895.24	−1	30n	III	25665.11	$a^5G'_6-a^5H'_6$	254
7	3889.96	0	6	III (A)	25699.94	$a^3F'_2-b^5D'_2$	249
7	3888.04	0	4n	IV	25712.64	$a^5G'_4-a^5G_4$	253
12	3887.33	−3	(1n)	....	25717.34	$a^5G'_4-a^5H'_3$	254
7	3884.04	−5	(2)	....	25739.12	$a^5G'_3-a^5G_2$	253
5	3882.87	0	20n	III?	25746.87	$a^5G'_6-a^5H'_7$	254
5	3882.34	+2	10n	III?	25750.39	$a^5G'_5-a^5H'_5$	254
5	3882.13	−1	15n	III?	25751.78	$a^5G'_5-a^5G_6$	253
4	3881.41	+2	4	IV?	25756.56	$a^3F'_3-b^5D'_4$	249
5	3877.60	0	2n	IV	25781.87	$a^5G'_3-a^5G_3$	253
7*	3875.29	+6 +3	20n	III	25797.23	$a^3F'_2-b^5D'_3$ $a^5G'_4-a^5G_5$	249 253
4	3873.25	+2	10n	III	25810.82	$a^5G'_4-a^5H'_4$	254
4	3869.60	+2	2n	IV?	25835.16	$aD-c^3P_1$	256
5	3869.32	+2	5n	IV?	25837.03	$a^5G'_2-a^5G_2$	253
4	3868.42	+1	10n	IV?	25843.04	$a^5G'_3-a^5G_4$	253
4	3867.77	+3	3	IV?	25847.39	$a^5G'_3-a^5H'_3$	254
4	3866.45	+1	15n	IV?	25856.20	$a^5G'_5-a^5H'_6$	254
4	3866.00	0	1	IV?	25859.22	$aD-c^3P_2$	256
4	3862.84	−1	10n	III	25880.38	$a^5G'_2-a^5G_3$	253
2	3861.08	......	3n	IV?	25892.18	....	......
4	3858.12	−1	15n	III	25912.03	$a^5G'_4-a^5H'_5$	254
5	3857.89	−1	2	III A?	25913.58	$b^3F'_4-e^3G'_5$	257
4	3853.74	0	10n	III	25941.49	$a^5G'_3-a^5H'_4$	254
4	3853.05	−2	10n	IV	25946.12	$a^5G'_2-a^5H'_3$	254
4	3848.29	−2	2	IV	25978.22	$b^3F'_3-e^3G'_4$	257
2	3846.44	......	6n	IV	25990.73	....	......
2	3842.61	−1	(3)	....	26016.61	$a^5F_5-d^5F'_4$	258
4	3841.67	+3	(1)	....	26022.99	$b^3F'_2-e^3G'_3$	257
2	3836.76	......	5	IV	26056.27	....	......
5	3833.91	−1	3	IV?	26075.65	$b^3F'_4-f^3F_4$	259
2	3833.67	......	4	III	26077.26	....	......
2	3833.19	......	4	IV	26080.59	....	......
4	3829.70	−3	2	IV?	26104.33	$b^3F'_3-f^3F_3$	259
7	3828.17	−2	3	III?	26114.75	$a^5F_5-d^5F'_5$	258
4	3827.62	0	1	IV?	26118.50	$a^3D'_3-d^3P'_2$	260
2	3827.48	+1	1	IV?	26119.45	$a^5F_3-d^5F'_2$	258
4	3826.95	−2	1	IV?	26123.08	$b^3F'_2-f^3F_2$	259
2	3822.03	−1	(2)	....	26156.73	$a^5F_4-d^5F'_4$	258
7	3821.74	+3	2	IV?	26158.69	$a^5F_2-d^5F'_1$	258
2	3818.20	0	(1)	....	26182.89	$a^3H'_6-g^3G'_5$	261
4	3817.65	0	5	IV?	26186.71	$a^5F_3-d^5F'_3$	258

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	3814.86	−2	4	IV?	26205.86	$a^5F_2-d^5F'_2$	258
2	3813.26	+1	(0)	....	26216.85	$a^5F_1-d^5F'_1$	258
2	3811.39	−7	4	IV?	26229.76	$a^3G_3-h^3F_2$	262
5*	3807.78	{+2 +1}	1	IV?	26254.59	{$a^5F_4-d^5F'_5$ $a^3G'_5-c^5H'_5$	258 263
5	3806.45	−1	1	IV?	26263.77	$a^5F_1-d^5F'_2$	258
5	3806.04	−1	1	IV?	26266.59	$c^3P'_2-g^3P_2$	264
7	3805.48	+2	1	IV?	26270.45	$a^5F_3-d^5F'_4$	258
7	3805.13	+1	1	IV?	26272.87	$a^5F_2-d^5F'_3$	258
7	3801.07	−2	3	IV	26300.93	$a^3G_4-h^3F_3$	262
4	3798.29	−1	6	IV	26320.18	$b^3F'_2-f^3D'_1$	265
4	3795.87	−1	7	IV	26336.97	$b^3F'_3-f^3D'_2$	265
4‡	3794.74	−3	(1)	(IV)	26344.80	$a^3P'_2-bP$	266
4	3793.67	−1	(1)	....	26352.24	$c^3P'_1-g^3P_2$	264
4	3789.28	+1	8	IV	26382.77	$b^3F'_4-f^3D'_3$	265
8	3788.80	0	2	III A	26386.11	$a^3F'_4-b^5G'_5$	267
7	3786.27	−1	3	IV	26403.74	$a^3G_5-h^3F_4$	262
12	3786.16	−2	(1)	(V)	26404.49	$a^3D'_3-f^3F'_4$	268
7	3786.03	0	20	II	26405.41	$aD-aP$	269
7	3782.14	+2	2	III A	26432.57	$a^3P'_2-cD'$	270
4	3779.03	+3	(1)	(V)	26454.33	$a^3P'_1-bP$	266
4	3774.32	−1	1n	IV	26487.35	$a^3F'_3-b^5G'_4$	267
7	3771.64	0	25	I	26506.15	$a^3F'_4-c^3F_3$	271
7	3766.46	0	3	IV A	26542.61	$a^3P'_1-cD'$	270
4	3754.93	0	1	IV	26624.11	$a^3G_4-d^3H_4$	272
7	3753.63	0	25	I	26633.33	$a^3F'_3-c^3F_2$	271
7	3752.87	+1	8or	I	26638.72	$a^3F'_4-c^3F_4$	271
4	3748.07	0	6n	IV	26672.84	$a^3G_3-d^3H_4$	272
4	3747.80	−1	1	IV	26674.76	$a^3G_5-d^3H_5$	272
7	3741.14	+3	1	IV	26722.24	$a^3G'_5-g^5F'_5$	273
7	3741.06	+1	6or	I	26722.81	$a^3F'_3-c^3F_3$	271
7	3738.90	+1	5n	IV	26738.25	$a^3G_4-d^3H_5$	272
2	3735.66	......	4n	IV	26761.45	....	......
7	3733.78	0	4n	IV	26774.92	$a^3G_5-d^3H_6$	272
7	3729.77	−3	5or	I	26803.71	$a^3F'_2-c^3F_2$	271
11	3728.66	−3	1	IV	26811.68	$b^3F'_3-g^3F_2$	274
12	3727.05	+1	(1)	(III A)	26823.30	$aD-e^3F_3$	275
7	3725.12	−2	20	III	26837.17	$a^3P'_2-b^3S'_1$	276
4	3724.59	+1	20	III	26840.99	$aG-cG'$	277
4	3722.58	+1	15?	II?	26855.47	$a^3F'_3-c^3F_4$	271
8	3720.38	0	2	IV	26871.36	$a^5G'_6-d^5F'_5$	278
7	3717.39	0	20	I	26892.97	$a^3F'_2-c^3F_3$	271
8	3717.26	−1	1	IV A	26893.91	$b^3F'_4-g^3F_4$	274
8	3715.79	0	1	IV A	26904.55	$b^3F'_3-g^3F_3$	274
7	3715.33	......	3n	IV	26907.88	....	......
4	3713.70	−3	1	IV A	26919.68	$b^3F'_2-g^3F_2$	274
12	3710.17	−1	(0)	....	26945.39	$b^3P'_2-g^3P_1$	279
7	3709.95	+1	20	III	26946.89	$a^3P'_1-b^3S'_1$	276
2	3708.63	0	4n	IV	26956.52	$a^3F_4-f^3F'_4$	280
7*	3707.53	0	10n	IV	26964.49	$a^5G'_5-d^5F'_4$	278
4‖	3705.53	+2	(1)	....	26979.03	$b^3P'_1-g^3P_0$	279
7	3704.29	0	15	III	26988.06	$b^3F'_4-g^3D'_3$	281
7	3702.98	−1	2	IV	26997.62	$aG-c^3H_4$	282

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	3702.29	+1	10	III	27002.65	$a^3P'_0-b^3S'_1$	276
7	3700.05	......	4n	IV	27018.99	......	......
6	3698.41	−1	(1−)	......	27030.97	$b^3F'_3-g^3F_4$	274
7	3698.17	−1	3	IV	27032.73	$b^3P'_2-g^3P_2$	279
7	3696.88	−1	2	IV	27042.16	$a^5G'_4-d^5F'_3$	278
7	3694.43	0	10	III	27060.10	$b^3F'_3-g^3D'_2$	281
7	3689.89	−2	15	I	27093.39	$a^3F'_4-c^3D'_3$	283
12	3689.67	0	(0)	......	27095.00	$b^3P'_0-g^3P_1$	279
4	3687.38	+3	5	III A	27111.83	$a^3F'_4-b^3G'_3$	284
12	3686.71	−3	(0)	......	27116.75	$b^3P'_1-g^3P_2$	279
7	3685.95	+1	2	IV A	27122.35	$b^3F'_2-g^3D'_1$	281
5	3681.23	−3	1	IV	27157.12	$a^5G'_2-d^5F'_1$	278
7	3679.68	......	3	IV	27168.57	......	......
5	3677.75	−2	tr	IV A	27182.82	$b^3F'_4-cG'$	285
7	3671.66	−1	20	I	27227.91	$a^3F'_4-b^3G'_4$	284
7	3668.95	−1	15	I	27248.01	$a^3F'_3-c^3D'_2$	283
7	3660.62	0	12	I	27310.02	$a^3F'_3-c^3D'_3$	283
7	3658.14	+3	20	I	27328.54	$a^3F'_3-b^3G'_3$	284
7	3654.58	0	15	I	27355.15	$a^3F'_2-c^3D'_1$	283
7	3653.49	−1	100r	I	27363.32	$a^3F'_4-b^3G'_5$	284
7	3646.19	0	12	I	27418.10	$a^3F'_2-c^3D'_2$	283
7	3644.69	......	4	IV	27429.37	......	......
7	3644.46	+1	1	IV	27431.10	$aG'-dG$	286
7	3642.68	+1	80r	I	27444.52	$a^3F'_3-b^3G'_4$	284
4	3640.33	+4	1	IV	27462.24	$a^5D'_4-e^5F'_5$	287
7	3637.97	+1	10	II	27480.05	$a^3F'_2-c^3D'_3$	283
7	3635.47	−1	80r	I	27498.95	$a^3F'_2-b^3G'_3$	284
7	3635.20	−2	8	II	27500.98	$a^3F'_4-a^5P_3$	288
4	3633.45	......	5	IV	27514.24	......	......
4	3632.00	......	3	IV	27525.22	......	......
7	3626.09	0	4	III A	27570.08	$a^3F'_3-a^5P_2$	288
4	3623.10	......	3	IV	27592.83	......	......
5	3620.00	+1	1	IV	27616.46	$a^3F_3-g^3F'_3$	289
7	3619.45	+1	1	IV	27620.65	$a^3F_4-g^3F'_4$	289
4	3617.21	0	1	IV	27637.76	$a^3D_3-g^3P_2$	290
7	3614.20	......	3	IV	27660.77	......	......
11	3613.44	0	(1u)	......	27666.59	$a^3D_2-g^3P_1$	290
9	3612.84	−1	(0u)	......	27671.19	$a^3D_1-g^3P_0$	290
4‡	3610.16	0	12	III	27691.73	$aD-bP$	291
4	3609.61	+1	1	IV A	27695.95	$a^3P'_2-b^5P_1$	292
7	3607.12	+1	2	IV	27715.07	$a^3F_2-g^3F'_3$	289
4	3606.81	+2	4	III A	27717.45	$a^3F'_3-a^5P_3$	288
7	3606.06	+2	1	IV	27723.21	$aF-dD$	293
7	3604.30	0	8	III	27736.75	$a^3F'_3-bD'$	294
4	3603.86	+1	2	III A	27740.14	$a^3F'_2-a^5P_2$	288
9	3602.02	−5	(0u)	......	27754.30	$a^3D_2-g^3P_2$	290
5	3601.16	+1	1	IV	27760.92	$aS-eP$	295
7	3598.71	0	15	III	27779.84	$aD-cD'$	296
7	3585.86	......	4	III?	27879.38	......	......
4	3578.25	−1	3	IV?	27938.67	$b^3F'_4-h^3D'_3$	297
8	3574.24	+1	8	III	27970.01	$bG-fG'$	298
6‡	3564.51	−3	(1−)	......	28046.46	$b^3F'_3-h^3D'_2$	297
4	3564.4	−4	1	IV?	28047.23	$aD'-dD$	299

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
5	3558.51	.....	6?	IV	28093.65	....	.....
4	3556.17	.....	3	IV	28112.13	....	.....
6	3553.82	−5	(1)	....	28130.74	$b^3F'_2-h^3D'_1$	297
7	3547.01	−2	15	IV	28184.73	$aG-dF$	300
4	3542.51	−2	3	IV?	28220.53	$a^3H'_4-fG'$	301
7	3530.58	−1	1	III A	28315.89	$a^3F'_4-b^5F_3$	302
8	3525.16	0	3	III	28359.42	$a^3G_3-i^3F_2$	303
8	3519.94	0	1	III A	28401.47	$a^3F'_4-b^5F_4$	302
7	3516.84	−3	3	IV	28426.52	$a^3G_4-i^3F_3$	303
8	3511.64	+1	3	III A	28468.60	$a^3F'_3-b^5F_2$	302
7	3507.43	.....	3	IV	28502.77	....	.....
7	3506.64	0	8	I	28509.20	$a^3F'_4-b^5F_5$	302
8	3504.78	−3	2	III A	28524.33	$a^3G_5-i^3F_4$	303
4	3503.76	−1	1	III A	28532.62	$a^3F'_3-b^5F_3$	302
7	3499.10	0	8	III	28570.62	$a^3P'_2-d^3P_1$	304
8	3495.94	0	2	III A	28596.45	$a^3F'_2-b^5F_1$	302
7	3495.73	0	6	III A	28598.17	$a^3P'_1-d^3P_0$	304
7	3493.27	−1	4	II A	28618.31	$a^3F'_3-b^5F_4$	302
8	3490.77	0	1	III A	28638.81	$a^3F'_2-b^5F_2$	302
7	3485.69	0	6	III	28680.54	$a^3P'_1-d^3P_1$	304
4	3483.00	0	(1)	....	28702.69	$a^3F'_2-b^5F_3$	302
7	3481.68	0	3	IV	28713.58	$a^3D'_3-b^3D_3$	305
8	3481.11	0	3	IV	28718.27	$a^3D'_2-b^3D_2$	305
7	3480.53	0	12	III	28723.06	$a^3P'_2-d^3P_2$	304
7	3478.92	0	6	III A	28736.35	$a^3P'_0-d^3P_1$	304
7	3476.45	−1	3	III A	28756.77	$a^3P'_2-b^5S'_2$	306
4	3472.81	0	2	IV	28786.91	$a^3D'_1-b^3D_1$	305
8	3467.26	0	6	III A	28832.98	$a^3P'_1-d^3P_2$	304
8	3463.20	−2	1	III A	28866.79	$a^3P'_1-b^5S'_2$	306
8	3459.41	.....	3	III	28898.42	....	.....
8	3458.01	0	3	III A	28910.12	$a^5F'_4-d^5D'_3$	307
7	3457.49	0	4	III	28914.47	$a^5F'_5-d^5D'_4$	307
8	3457.29	0	2	III A	28916.14	$a^5F'_3-d^5D'_2$	307
8	3456.65	0	6	III	28921.49	$aG-bH$	308
8	3455.76	0	1	III A	28928.94	$a^5F'_2-d^5D'_1$	307
8	3455.43	+2	1	IV	28931.70	$a^5F_3-e^5F'_3$	309
8	3455.37	+1	2	IV	28932.21	$a^5F_4-e^5F'_4$	309
8	3454.73	+3	tr	IV	28937.56	$a^5F_2-e^5F'_2$	309
8*	3454.17	+1 −3	1	III A	28942.25	$a^5F_5-e^5F'_5$ $a^3G_5-g^3G'_4$	309 310
8	3453.66	0	tr	III A	28946.53	$a^5F'_1-d^5D'_0$	307
4	3453.55	+1	(1)	....	28947.44	$a^5F_1-e^5F'_1$	309
8	3450.75	0	1	III A	28970.93	$a^5F'_1-d^5D'_1$	307
8	3449.87	0	2	III A	28978.32	$a^5F'_2-d^5D'_2$	307
8	3448.25	0	1	III A	28991.93	$a^5F'_3-d^5D'_3$	307
8	3446.6	−2	2	IV	29005.81	$a^3G_4-g^3G'_4$	310
8	3445.55	+1	1	III A	29014.65	$a^5F'_4-d^5D'_4$	307
8	3444.89	0	tr	IV A	29020.22	$a^3P'_2-cF$	311
8	3444.41	0	3	III A	29024.26	$b^3F'_2-i^3D'_1$	312
7	3443.64	0	5	III	29030.74	$b^3F'_3-i^3D'_2$	312
7	3439.30	−1	8	III	29067.39	$b^3F'_4-i^3D'_3$	312
4	3435.40	.....	3	III	29100.38	....	.....
12	3431.86	−3	(1)	....	29130.40	$a^3P'_1-cF$	311

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multi-plet
8........	3430.88	+1	2	III	29138.71	$b^3F'_2-i^3D'_2$	312
8........	3430.54	−1	1	III A	29141.60	$a^3P'_2-f^3F_3$	313
7........	3428.95	0	4	III	29155.12	$a^3G_5-g^3G'_5$	310
8........	3428.12	+1	1	IV A	29162.18	$a^3P'_1-f^3F_2$	313
8........	3423.18	+1	2	IV A	29204.25	$b^3F'_3-i^3D'_3$	312
7........	3415.99	+1	5	IV	29265.72	$a^3F_4-b^3D_3$	314
7........	3411.67	0	5	IV	29302.77	$a^3F_3-b^3D_2$	314
7........	3405.09	0	5	III A	29359.40	$a^3P'_1-f^3D'_1$	315
7........	3403.36	0	4	III A	29374.33	$a^3P'_2-f^3D'_2$	315
4........	3400.14	−3	3	IV	29402.14	$a^3F_2-b^3D_1$	314
7........	3398.62	−1	8	III	29415.28	$a^3P'_0-f^3D'_1$	315
8........	3392.79	0	1	IV	29465.83	$a^5D'_3-d^5D_3$	316
8........	3392.71	+3	10	III	29466.53	aG−eF	317
7........	3390.67	0	10	III	29484.27	$a^3P'_1-f^3D'_2$	315
8........	3389.90	−1	1n	IV	29490.96	$a^5D'_4-d^5D_4$	316
8........	3389.60	0	1	IV	29493.57	$a^3D'_3-c^3D_3$	318
7........	3385.93	−1	40r	II	29525.53	$a^3F'_4-d^3D'_3$	319
8........	3385.66	0	12	I	29527.89	$a^3F'_4-c^3G'_3$	320
7........	3382.30	+1	15	II	29557.22	$a^3P'_2-f^3D'_3$	315
8........	3381.44	0	2	IV	29564.74	$b^3F'_4-f^3G'_5$	321
8........	3381.35	+1	1	IV	29565.52	$a^3D'_2-c^3D_2$	318
8........	3380.12	−3	1	IV	29576.28	$a^5D'_1-g^5F'_1$	322
8........	3379.43	0	1	IV	29582.32	$a^5D'_2-g^5F'_2$	322
7........	3379.20	−1	15	I	29584.33	$a^3F'_4-c^3G'_4$	320
8........	3377.57	−1	30r	I	29598.62	$a^3F'_3-d^3D'_2$	319
8........	3377.48	−1	20	I	29599.41	$a^3F'_4-c^5D'_3$	323
8........	3375.69	−2	3n	III	29615.09	$a^5D'_3-g^5F'_3$	322
8........	3374.60	−1	1	IV	29624.66	$a^5D'_1-g^5F'_2$	322
8*.......	3373.58	0 +2	1	IV	29633.61	$a^5D'_4-g^5F'_4$ $a^3D'_1-c^3D_2$	322 318
7........	3371.44	+1	80R	II	29652.43	$a^3F'_4-c^3G'_5$	320
7........	3370.42	−2	40r	II	29661.41	$a^3F'_2-d^3D'_1$	319
8........	3369.05	0	1	III A	29673.46	$a^3F'_4-c^5D'_4$	323
7........	3367.87	−1	3n	III	29683.86	$a^5D'_2-g^5F'_3$	322
7§.......	3366.17	+2	5	III E	29698.84	$a^5G'_6-e^5F'_5$	324
8........	3363.60	−3	2n	IV	29721.54	aF−dG	325
7........	3362.10	0	3	III	29734.80	$a^5D'_3-g^5F'_4$	322
7........	3361.82	−1	10	I	29737.27	$a^3F'_3-c^5D'_2$	323
8........	3361.50	0	1	III A	29740.11	$a^5G'_5-e^5F'_4$	324
12¶......	3361.27	+1	40r	I	29742.14	$a^3F'_3-d^3D'_3$	319
4........	3361.00	+1	10	I	29744.53	$a^3F'_3-c^3G'_3$	320
7........	3358.47	−1	8n	IV	29766.94	$a^5D'_4-g^5F'_5$	322
7........	3358.26	−1	10	I	29768.79	$a^3F'_2-d^3D'_2$	319
8........	3356.18	−1	2	III	29787.25	$a^5G'_4-e^5F'_3$	324
7........	3354.64	+1	60r	II	29800.92	$a^3F'_3-c^3G'_4$	320
7........	3352.92	+1	6	I A	29816.21	$a^3F'_3-c^5D'_3$	323
8........	3350.53	−1	2	IV	29837.47	$a^5G'_3-e^5F'_2$	324
12.......	3349.24	0	(?)	(III A)	29848.88	$a^3P'_2-g^3F_2$	326
8........	3348.52	−1	5	II A	29855.38	$a^3F'_2-c^5D'_1$	323
8........	3344.91	−1	1	III A	29887.60	$a^5G'_2-e^5F'_1$	324
8........	3344.7	+8	tr	IV A	29889.49	$a^5G'_5-e^5F'_5$	324
8........	3343.34	−1	tr	IV A	29901.64	$a^5G'_4-e^5F'_4$	324
7........	3342.70	−1	2	II A	29907.36	$a^3F'_2-c^5D'_2$	323

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	3342.14	0	6	I A	29912.37	$a^3F'_2-d^3D'_3$	319
7**	3341.87	0	5or	II	29914.79	$a^3F'_2-c^3G'_3$	320
8*	3341.54	0 −1	1	III A	29917.74	$aD-d^3P_1$ $a^5G'_3-e^5F'_3$	327 324
12	3340.77	−2	(1)	(V)	29924.58	$a^5F_5-c^5G_4$	328
8	3339.5	−2	1n	IV	29936.03	$a^5G'_2-e^5F'_2$	324
8	3338.82	−2	2	III A	29942.13	$a^3P'_2-g^3F_3$	326
8	3337.40	+1	1n	IV	29954.86	$a^5F_4-c^5G_3$	328
8	3336.94	−2	1	IV A	29958.99	$a^3P'_1-g^3F_2$	326
8	3334.88	−1	1	IV	29977.49	$a^5D'_4-h^5F'_4$	329
12	3334.35	+3	(1n)	(IV)	29982.25	$a^5F_3-c^5G_2$	328
8	3333.91	0	2	III A	29986.21	$a^3F'_2-c^5D'_3$	323
8*	3333.02	+1 −1	2n	IV	29994.22	$a^5D'_3-h^5F'_3$ $a^5D'_2-h^5F'_2$	329 329
8	3328.34	−1	1	IV	30036.40	$a^5D'_1-h^5F'_2$	329
8	3327.3	0	1n	IV	30045.77	$a^3F_4-c^3D_3$	330
8	3326.64	+1	2	III A	30051.74	$a^3P'_2-g^3D'_1$	331
8	3325.37	0	1n	IV	30063.23	$a^5D'_2-h^5F'_3$	329
8	3325.22	0	3	IV	30064.58	$a^5F_4-c^5G_4$	328
8	3325.15	0	3	IV	30065.21	$a^5F_5-c^5G_5$	328
8*	3324.74	−2 −1	4	III	30068.93	$a^5F_2-c^5G_2$ $a^5F_3-c^5G_3$	328 328
8	3324.61	+1	1	III A	30070.09	$aD-d^3P_2$	327
8	3323.89	−1	2	IV A	30076.61	$a^5D'_4-h^5F'_5$	329
8	3323.80	+1	4	III	30077.42	$bG-fF$	332
8	3323.66	0	2n	IV	30078.68	$a^5D'_3-h^5F'_4$	329
7	3321.58	0	8	III	30097.53	$a^3P'_2-g^3D'_2$	331
7	3318.35	−1	4	IV	30126.82	$a^5F_1-c^5G_2$	328
8	3316.38	−2	1	IV	30144.71	$a^5D'_4-b^3D_3$	333
8	3315.78	−1	2n	IV	30150.17	$a^3F_3-c^3D_2$	330
8	3315.22	−2	2	IV	30155.26	$a^5F_2-c^5G_3$	328
8	3314.50	−1	8	III	30161.82	$a^3P'_1-g^3D'_1$	331
8	3314.42	0	10	I	30162.55	$a^3P'_2-g^3D'_3$	331
7	3312.68	+1	5	III	30178.37	$a^5F_3-c^5G_4$	328
7	3309.71	−1	6	III	30205.46	$a^5F_4-c^5G_5$	328
4	3309.49	0	15	I	30207.46	$a^3P'_1-g^3D'_2$	331
7	3308.38	−1	10	III	30217.61	$a^3P'_0-g^3D'_1$	331
7	3306.87	0	10	III	30231.40	$a^5F_5-c^5G_6$	328
8	3305.75	−2	2	IV	30241.63	$a^5D'_1-b^3D_2$	333
8	3305.29	−1	2	IV	30245.86	$a^5D'_3-b^3D_3$	333
8	3299.41	−1	10	III	30299.75	$aD-e^3G'_3$	334
8	3297.78	−1	1	IV	30314.72	$a^5D'_2-b^3D_3$	333
8	3297.24	−1	1	IV	30319.69	$a^5D'_1-e^5D_0$	335
8	3297.08	−1	1	IV	30321.16	$a^5D'_3-e^5D_2$	335
12	3296.21	0	(1)	....	30329.18	$a^5D'_4-e^5D_3$	335
8	3295.64	0	1	IV A	30334.42	$a^5D'_2-e^5D_1$	335
7	3294.89	−1	6	IV	30341.32	$a^5D'_4-e^5D_4$	335
7	3292.06	−1	20	I	30367.40	$aD-cF$	336
12	3291.07	+1	(0)	....	30376.52	$a^5D'_1-e^5D_1$	335
12	3289.58	−3	(0)	....	30390.26	$a^5D'_2-e^5D_2$	335
12	3288.89	0	(1)	....	30396.67	$a^5D'_0-e^5D_1$	335
7	3288.13	......	3	IV	30403.69	....	......

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
8........	3285.24	0	2	IV	30430.44	$a^5D'_3-e^5D_3$	335
8........	3285.04	−1	1	IV	30432.29	$a^5D'_1-e^5D_2$	335
8........	3283.94	0	2	IV	30442.49	$a^5D'_3-e^5D_4$	335
8........	3280.38	+1	2	III A	30475.52	$a^3P'_2-cP$	337
8........	3278.96	0	[12]	III A	30488.71	$aD-f^3F_3$	338
12........	3277.82	0	(1)	(IV)	30499.40	$a^5D'_2-e^5D_3$	335
4........	3274.05	0	(5)	(III A)	30534.44	$b^3F'_4-j^3D'_3$	339
7........	3270.56	0	3	III A	30567.03	$b^3F'_3-j^3D'_2$	339
8........	3268.60	+2	1	III A	30585.35	$a^3P'_1-cP$	337
8........	3267.41	+1	tr	IV A	30596.50	$aD-f^3D'_1$	340
8........	3267.06	+1	2n	III	30599.77	$b^3F'_4-k^3D'_3$	341
8........	3265.46	−2	2	III A	30614.75	$b^3F'_2-j^3D'_1$	339
8........	3263.83	−2	2n	III	30630.05	$b^3F'_3-k^3D'_2$	341
8........	3262.63	0	1	IV A	30641.31	$a^3P'_0-cP$	337
8........	3260.39	−3	1	IV	30662.37	$b^3F'_2-k^3D'_1$	341
8§........	3260.26	−2	3	III E	30663.59	$a^3P'_2-dP$	342
8........	3259.41	−1	2	IV	30671.58	$b^3F'_3-j^3D'_3$	339
8........	3259.04	0	1	IV A	30675.06	$b^3F'_2-j^3D'_2$	339
7§........	3248.60	−3	15	III Er	30773.63	$a^3P'_1-dP$	342
8........	3243.80	0	4	III A	30819.18	$a^3F'_4-e^3D'_3$	343
8........	3243.51	+1	3	III	30821.93	$a^5G'_6-c^5G_5$	344
7........	3238.20	−1	4	IV	30872.47	$a^5G'_5-c^5G_4$	344
8........	3236.21	−1	tr	III A	30891.45	$a^5F_5-c^5H'_6$	345
12........	3233.62	−1	(1)	....	30919.08	$a^5F_4-c^5H'_5$	345
8........	3232.78	0	3	IV	30924.23	$a^5G'_4-c^5G_3$	344
8........	3229.86	0	tr	IV A	30952.18	$a^5F_3-c^5H'_4$	345
8........	3228.17	−1	2	III	30968.39	$a^5G'_3-c^5G_2$	344
8........	3227.94	+1	2N	III	30970.60	$a^5F_5-d^5D_4$	346
8........	3226.49	0	1N	IV	30984.52	$a^5F_4-d^5D_3$	346
8........	3226.22	−1	1	III A	30987.11	$a^3F'_4-d^3G'_3$	347
7........	3226.11	0	12	III	30988.16	$a^5G'_6-c^5G_6$	344
8........	3223.51	0	10	III	31013.16	$a^5G'_5-c^5G_5$	344
8........	3223.00	0	2N	III	31018.06	$a^5F_5-d^5G_6$	348
8........	3222.74	0	3	II A	31020.57	$a^3F'_3-e^3D'_2$	343
7........	3221.37	0	10	III	31033.77	$a^5G'_4-c^5G_4$	344
8........	3221.14	0	2	III A	31035.98	$a^3F'_3-e^3D'_3$	343
8........	3220.28	−1	1	III A	31044.26	$a^5F_4-d^5G_5$	348
8........	3219.33	0	1n?	III	31053.43	$a^5F_1-d^5G_2$	348
7........	3219.21	+1	8	III	31054.58	$a^5G'_3-c^5G_3$	344
8........	3218.98	−1	2N	III	31056.80	$a^5F_3-d^5G_4$	348
8........	3218.67	−1	tr	IV A	31059.79	$a^3P'_2-h^3D'_1$	349
12........	3218.47	−1	(0N)	(IV)	31061.70	$a^5F_2-d^5G_3$	348
7........	3217.95	0	8	III	31066.74	$a^5G'_2-c^5G_2$	344
8........	3216.19	−1	3	III A	31083.74	$a^3P'_2-h^3D'_2$	349
7........	3214.23	−1	12	I	31102.70	$a^3F'_4-d^3G'_4$	347
7*........	3213.14	−2 +1	8	III	31113.25	$a^3P'_2-h^3D'_3$ $a^5F_5-g^5F'_4$	349 350
8........	3211.07	+3	1n	IV	31133.30	$a^5F_4-g^5F'_3$	350
7........	3209.02	−1	4	IV	31153.20	$a^5G'_2-c^5G_3$	344
7........	3207.90	+2	5	IV	31164.06	$a^5G'_3-c^5G_4$	344
7........	3207.33	+1	5	III	31169.60	$a^3P'_1-h^3D'_1$	349
7........	3206.82	+1	5	IV	31174.56	$a^5G'_4-c^5G_5$	344
7........	3206.34	+1	5	IV	31179.23	$a^5G'_5-c^5G_6$	344

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
7	3205.85	0	5	II	31184.00	$a^3F'_2-e^3D'_1$	343
8	3205.15	−1	2	III A	31190.80	$a^3F'_2-e^3D'_2$	343
7	3204.87	+1	6	III	31193.52	$a^3P'_1-h^3D'_2$	349
7	3203.82	0	15	I	31203.75	$a^3F'_3-d^3G'_3$	347
7	3201.59	0	5	III	31225.49	$a^3P'_0-h^3D'_1$	349
7	3199.91	0	100R	II	31241.88	$a^3F'_4-d^3G'_5$	347
8	3199.43	+1	1n	IV A	31246.58	$a^5F_5-g^5F'_5$	350
12	3199.34	0	(1n)	(IV A)	31247.45	$a^5F_3-g^5F'_3$	350
8	3198.71	−1	1n	IV A	31253.61	$a^5F_4-g^5F'_4$	350
7	3192.00	+1	80R	II	31319.29	$a^3F'_3-d^3G'_4$	347
7	3186.45	0	60r	II	31373.83	$a^3F'_2-d^3G'_3$	347
7	3179.28	+1	3	III A	31444.59	$aD-g^3D'_2$	351
7	3172.72	+1	4	III A	31509.61	$aD-g^3D'_3$	351
8	3172.38	0	1n	IV	31512.99	$a^5F_4-h^5F'_3$	352
7	3170.92	−1	3	III A	31527.49	$a^3F'_4-a^3H_5$	353
8*	3168.04	{+1 −3}	2n	IV	31556.15	{$a^5F_5-h^5F'_5$ $aG-eG'$	352 354
8	3163.92	+1	1	IV	31597.24	$a^5F_4-h^5F'_4$	352
12	3160.95	−1	(0)	(IV)	31626.93	$a^5F_3-h^5F'_3$	352
8	3160.09	+3	tr	III A	31635.54	$a^3F'_3-b^3P_2$	355
8	3157.66	0	1	III A	31659.88	$a^3F'_3-a^3H_4$	353
7	3153.59	......	3	III A	31700.75	....	......
8	3151.11	+1	tr	IV A	31725.69	$a^3F'_2-b^3P_1$	355
8	3147.42	+1	1	IV A	31762.87	$a^5F_3-b^3D_2$	356
7	3147.26	−1	3	IV A	31764.49	$a^5F_4-b^3D_3$	356
8	3146.24	0	3N	IV	31774.80	$a^5G'_6-d^5G_6$	357
8	3145.51	0	1	IV A	31782.18	$a^3P'_2-e^3P_1$	358
8	3143.34	0	12N	IV	31804.12	$a^5G'_6-c^5H'_7$	359
7	3141.67	0	10	IV	31821.01	$a^5F_5-e^5D_4$	360
7	3141.51	+1	15	II	31822.63	$aD-cP$	361
8	3139.87	+1	10N	IV	31839.25	$a^5G'_5-c^5H'_6$	359
4	3138.87	+2	(1)	....	31849.40	$a^5F_2-b^3D_1$	356
8	3138.62	0	1n	IV A	31851.94	$a^5G'_5-d^5G_5$	357
12	3137.36	−1	(1)	....	31864.72	$a^3P'_2-e^3P_2$	358
4*	3136.03	{0 +1}	2	IV	31878.25	{$a^3P'_1-e^3P_0$ $a^5F_3-b^3D_3$	358 356
8	3135.05	0	8N	IV	31888.20	$a^5G'_4-c^5H'_5$	359
8	3134.66	−1	1	IV A	31892.17	$a^3P'_1-e^3P_1$	358
8	3133.13	−1	1	IV A	31907.74	$a^5F_1-b^3D_1$	356
8	3132.71	0	6N	IV	31912.03	$a^5G'_4-d^5G_4$	357
8	3132.1	......	3N	IV	31918.23	....	......
8††	3130.81	......	15?	IV	31931.39	....	......
8	3130.38	0	1	IV A	31935.78	$b^3F'_2-i^3F_2$	362
8	3130.16	0	8N	IV	31938.02	$a^5G'_3-c^5H'_4$	359
8	3129.62	−2	1	IV A	31943.53	$b^3F'_3-i^3F_3$	362
7	3129.07	0	7	IV	31949.14	$a^5F_4-e^5D_3$	360
7*	3128.64	{+1 +1}	8	IV	31953.53	{$a^3P'_2-i^3D'_1$ $a^5F_3-e^5D_2$	363 360
8*	3127.90	{+1 +1}	5	IV	31961.09	{$a^5F_4-e^5D_4$ $a^5G'_3-d^5G_3$	360 357
8	3127.67	0	8N	IV	31963.44	$a^5G'_2-c^5H'_3$	359
8	3127.43	+1	?	IV A	31965.90	$a^5G'_5-d^5G_6$	357
8	3127.23	−3	2	IV	31967.94	$b^3F'_4-i^3F_4$	362

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
12‡‡......	3125.64	+1	(2)	(IV)	31984.23	$a^5F_2-e^5D_1$	360
8........	3125.55	0	2	IV	31985.13	$a^5F_1-e^5D_0$	360
8........	3124.74	0	1	IV A	31993.41	$a^5G'_2-d^5G_2$	357
7........	3123.76	−1	20n	IV	32003.45	$a^5G'_6-g^5F'_5$	364
7........	3123.07	0	15	II	32010.51	aD−dP	365
8........	3122.80	+1	tr	IV A	32013.29	$a^5G'_4-d^5G_5$	357
8........	3120.21	0	3	IV	32039.85	$a^5F_2-e^5D_2$	360
8*.......	3119.97	0 +2	2	IV	32042.32	$a^5F_1-e^5D_1$ $a^5G'_3-d^5G_4$	360 357
8........	3119.73	0	15	III	32044.78	aG−cH	366
7........	3118.13	+1	15	IV	32061.23	$a^5G'_5-g^5F'_4$	364
8........	3117.89	−1	5	III A	32063.70	$a^3P'_1-i^3D'_1$	363
7........	3117.45	0	6	III	32068.22	$a^3P'_2-i^3D'_2$	363
7........	3114.09	0	20n	IV	32102.82	$a^5G'_4-g^5F'_3$	364
7........	3112.48	−1	8	III	32119.44	$a^3P'_0-i^3D'_1$	363
7........	3111.28	0	10n	IV	32131.83	$a^5G'_3-g^5F'_2$	364
8§.......	3110.61	......	4	IV	32138.74	....	......
7........	3109.58	......	8n	IV	32149.39	....	......
7........	3107.45	+2	12n	IV	32171.42	$a^5G'_2-g^5F'_1$	364
7........	3106.80	0	8	III A	32178.15	$a^3P'_1-i^3D'_2$	363
8........	3105.22	+1	2n	IV	32194.52	$a^5G'_5-g^5F'_5$	364
8........	3102.50	0	3n	III	32222.74	$a^5G'_4-g^5F'_4$	364
8........	3101.77	−1	1n	IV A	32230.33	$a^5G'_2-g^5F'_2$	364
8........	3101.48	−1	4n	III	32233.35	$a^5G'_3-g^5F'_3$	364
8*.......	3100.67	0 0	12	III A	32241.76	$a^3P'_2-c^3S'_1$ $a^3P'_2-i^3D'_3$	367 363
8........	3093.83	0	3n	IV	32313.04	$a^5G'_6-h^5F'_5$	368
7........	3090.13	0	8	III	32351.73	$a^3P'_1-c^3S'_1$	367
8........	3086.82	−1	1	IV A	32386.42	$b^3F'_4-cH$	369
8........	3085.03	0	2n	IV	32405.20	$a^5G'_5-h^5F'_4$	368
7........	3084.81	0	4	III A	32407.52	$a^3P'_0-c^3S'_1$	367
8........	3082.62	+2	2	III A	32430.55	$aD-h^3D'_2$	370
7........	3080.17	−1	1	III	32456.34	$b^3F'_4-l^3D'_3$	371
8........	3079.82	+2	1	III A	32460.03	$aD-h^3D'_3$	370
12........	3077.72	0	(1)	(IV)	32482.17	$a^5G'_4-h^5F'_3$	368
12........	3071.92	+1	(0)	(IV)	32543.50	$a^5G'_3-h^5F'_2$	368
7........	3042.54	0	3	III A	32857.73	$a^3F'_2-bF$	372
8........	3025.06	+1	2	III	33047.59	aD−dF	373
8........	3021.56	......	3	IV	33085.89	....	......
8........	3015.55	......	4n	IV	33151.81	....	......
8........	3010.12	+1	tr	IV A	33211.61	$aD-e^3P_2$	374
8........	3007.48	......	4N	IV	33240.78	....	......
8........	3005.37	0	2n	IV A	33264.10	$b^3F'_4-j^3F_4$	375
8........	3003.65	0	2n	IV A	33283.15	$b^3F'_3-j^3F_3$	375
7*.......	3002.73	+1 +1	3	III A	33293.36	$a^3F'_4-d^3F_3$ $b^3F'_2-j^3F_2$	376 375
7........	3000.87	0	20	II	33313.98	$a^3F'_4-d^3F_4$	376
8........	2999.78	+1	tr	IV A	33326.08	$a^3P'_2-f^3P_2$	377
8........	2998.41	+2	tr	IV A	33341.31	$a^3P'_2-f^3P_1$	377
8........	2995.75	......	4	IV	33370.95	....	......
8........	2993.94	+1	tr	IV A	33391.09	$b^3F'_2-j^3F_3$	375
8........	2993.05	+1	tr	IV A	33401.01	$b^3F'_3-j^3F_4$	375
8........	2991.79	+2	1	IV A	33415.08	$aD-i^3D'_2$	378

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
8........	2990.98	0	3	IV A	33424.13	$b^3F'_3-m^3D'_2$	379
8........	2990.48	−3	3	IV A	33429.73	$b^3F'_4-m^3D'_3$	379
8........	2990.03	−2	3	IV A	33434.75	$b^3F'_2-m^3D'_1$	379
8........	2989.91	0	tr	IV A	33436.10	$a^3P'_1-f^3P_2$	377
8........	2985.46	−1	3	III A	33485.94	$a^3F'_3-d^3F_2$	376
7........	2983.29	−1	20	II	33510.29	$a^3F'_3-d^3F_3$	376
12§§......	2981.45	−2	(2)	(III A)	33530.98	$a^3F'_3-d^3F_4$	376
8........	2980.28	−2	tr	IV A	33544.14	$a^3P'_2-j^3D'_1$	380
8........	2976.32	+1	2	III A	33588.75	$aD-i^3D'_3$	378
7........	2974.93	0	4	III A	33604.46	$a^3P'_2-j^3D'_2$	380
7........	2970.55	−1	4	III A	33654.00	$a^3P'_1-j^3D'_1$	380
7........	2970.38	0	10	II A	33655.93	$a^3F'_2-d^3F_2$	376
8........	2969.37	−1	1	IV A	33667.37	$a^3P'_2-k^3D'_2$	381
7........	2968.23	0	4	III A	33680.30	$a^3F'_2-d^3F_3$	376
7........	2967.22	0	25	II	33691.77	$a^3F'_4-e^3F_3$	382
8........	2966.38	+1	1	IV	33701.31	$a^3P'_1-k^3D'_1$	381
8........	2965.72	+1	15	III	33708.80	$a^3P'_2-j^3D'_3$	380
7........	2965.68	+5	8	III	33709.26	$a^3P'_0-j^3D'_1$	380
4........	2965.24	+1	(6)?	....	33714.27	$a^3P'_1-j^3D'_2$	380
8........	2961.48	+2	2	III A	33757.06	$a^3P'_0-k^3D'_1$	381
8........	2959.98	+1	5	III A	33774.17	$a^3P'_2-k^3D'_3$	381
8........	2959.71	0	3	III A	33777.25	$a^3P'_1-k^3D'_2$	381
7........	2956.80	0	25	II	33810.50	$a^3F'_3-e^3F_2$	382
7........	2956.13	0	70R	II	33818.16	$a^3F'_4-e^3F_4$	382
7........	2948.25	0	60r	II	33908.55	$a^3F'_3-e^3F_3$	382
8........	2947.72	−1	3	III A	33914.63	$aD-f^3G'_3$	383
7........	2941.99	−1	60r	II	33980.69	$a^3F'_2-e^3F_2$	382
7........	2937.30	0	25	II	34034.96	$a^3F'_3-e^3F_4$	382
7........	2933.53	0	25	II	34078.68	$a^3F'_2-e^3F_3$	382
7........	2928.32	−1	30	III	34139.31	$aG-fG'$	384
8........	2922.92	−1	2	IV A	34202.39	$aD-h^3F_3$	385
8........	2912.47	0	2	IV A	34325.12	$a^3P'_2-eP$	386
7........	2912.07	+1	40	III	34329.80	$aD-eF$	387
7........	2905.65	......	5	IV A	34405.66	....	......
8........	2903.17	0	2	IV	34435.04	$a^3P'_1-eP$	386
12........	2892.77	......	[3]	[IV A]	34558.84	....	......
8........	2883.23	+1	1	IV A	34673.18	$aD-f^3P_2$	388
8........	2881.94	0	1	IV A	34688.70	$aD-f^3P_1$	388
8........	2860.27	+1	2	IV A	34951.49	$aD-j^3D'_2$	389
8........	2855.13	0	1	IV	35014.42	$aD-k^3D'_2$	390
8........	2853.43	−1	1	IV A	35035.27	$a^3F'_2-cD'$	391
8........	2836.60	0	1	IV A	35243.14	$a^5F'_4-e^5D'_3$	392
8........	2836.40	0	1n	IV A	35245.61	$a^5F'_3-e^5D'_2$	392
8........	2836.09	0	1	IV A	35249.47	$a^5F'_5-e^5D'_4$	392
8........	2835.63	0	2	IV	35255.19	$a^5F'_2-e^5D'_1$	392
8........	2834.75	0	2	IV A	35266.13	$a^5F'_1-e^5D'_0$	392
8........	2832.26	0	1n	IV A	35297.13	$a^5F'_1-e^5D'_1$	392
8........	2831.40	−1	1n	IV A	35307.85	$a^5F'_2-e^5D'_2$	392
8........	2830.03	0	2n	IV A	35324.95	$a^5F'_3-e^5D'_3$	392
8*........	2828.05	$\begin{cases}+1\\0\end{cases}$	2	IV A	35349.68	$\begin{cases}a^5F'_1-e^5D'_2\\a^5F'_4-e^5D'_4\end{cases}$	392 392
8........	2826.37	0	tr	IV A	35370.69	$a^3F'_4-d^5D'_4$	393
8........	2825.06	0	1	IV A	35387.09	$a^5F'_2-e^5D'_3$	392

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multi-plet
8........	2823.46	−1	1	IV A	35407.13	$a^3F'_3-d^5D'_2$	393
8........	2821.51	−1	1	IV A	35431.61	$a^5F'_3-e^5D'_4$	392
6........	2817.83	−7	(1)	....	35477.85	$a^3P'_2-l^3D'_2$	394
6........	2817.37	−4	(1)	....	35483.64	$a^3P'_1-l^3D'_1$	394
7........	2812.96	−3	2	IV A	35539.31	$a^3P'_0-l^3D'_1$	394
7........	2809.15	−5	5	III	35587.50	$a^3P'_1-l^3D'_2$	394
7........	2805.68	−6	6	III	35631.51	$a^3P'_2-l^3D'_3$	394
7........	2802.47	0	15	III	35672.31	aD−eP	395
4........	2758.06	0	20	III	36246.68	aG−fF	396
4........	2757.40	+1	6	III	36255.37	$a^3P'_2-d^3S'_1$	397
4........	2749.04	−1	5	III	36365.60	$a^3P'_1-d^3S'_1$	397
8........	2744.85	+1	5	....	36421.11	$a^3P'_0-d^3S'_1$	397
4........	2742.30	0	15	III	36454.99	aD−dD′	398
12........	2741.82	+1	(1)	....	36461.35	$a^3P'_2-m^3D'_2$	399
12........	2740.88	0	(2)	....	36473.86	$a^3P'_1-m^3D'_1$	399
8........	2739.80	+1	15	III	36488.24	$a^3P'_2-g^3P_1$	400
12........	2736.71	+2	(2)	....	36529.40	$a^3P'_0-m^3D'_1$	399
7........	2735.61	+1	6	III	36544.12	aD−eD′	401
7........	2735.29	0	10	III	36548.27	$a^3P'_1-g^3P_0$	400
8........	2733.27	+1	30	III	36575.48	$a^3P'_2-g^3P_2$	400
8........	2731.59	+3	7	III	36597.91	$a^3P'_1-g^3P_1$	400
8........	2731.14	0	4	....	36603.86	$a^3P'_2-m^3D'_3$	399
7........	2727.38	−3	8	III	36654.40	$a^3P'_0-g^3P_1$	400
8........	2725.08	+2	10	III	36685.33	$a^3P'_1-g^3P_2$	400
4........	2688.83	......	10	....	37179.88	....	......
12........	2685.14	+1	(3)	....	37230.97	$a^3F'_4-e^3G'_4$	402
4........	2684.85	......	5	....	37234.99	....	......
8........	2679.95	+3	20	IV	37303.07	$a^3F'_4-e^3G'_5$	402
12........	2676.09	+1	(1)	....	37356.89	$a^3F'_4-f^3F_3$	403
8........	2669.61	+2	15	IV	37447.55	$a^3F'_3-e^3G'_4$	402
8........	2669.27	+1	2	....	37452.32	$a^3F'_3-cF$	404
12........	2668.36	+3	(1)	....	37465.11	$a^3F'_4-f^3F_4$	403
4........	2661.98	+1	10	IV	37554.87	$a^3F'_2-e^3G'_3$	402
12........	2660.66	+2	(1)	....	37573.51	$a^3F'_3-f^3F_3$	403
8........	2657.19	0	10	IV	37622.58	$a^3F'_2-cF$	404
8........	2656.92	......	4	....	37626.39	....	......
8........	2656.38	......	4	....	37634.04	....	......
8........	2654.93	+1	5	....	37654.59	$a^3F'_2-f^3F_2$	403
12........	2653.02	+4	(2)	....	37681.71	$a^3F'_3-f^3F_4$	403
8........	2649.60	......	3	....	37730.33	....	......
4........	2649.31	......	4	....	37734.47	....	......
12........	2648.65	+1	(1)	....	37743.82	$a^3F'_2-f^3F_3$	403
8........	2646.65	+3	40	II	37772.39	$a^3F'_4-f^3D'_3$	405
8........	2644.28	+2	40	II	37806.31	$a^3F'_3-f^3D'_2$	405
8........	2641.12	+3	40	II	37851.48	$a^3F'_2-f^3D'_1$	405
12........	2636.16	+1	(1)	....	37922.69	$aD-g^3P_2$	406
8........	2632.42	+2	15	....	37976.55	$a^3F'_2-f^3D'_2$	405
4........	2631.55	+3	(1)	....	37989.12	$a^3F'_3-f^3D'_3$	405
8........	2619.94	0	10	IV	38157.45	$a^3F'_4-g^3F_3$	407
4........	2611.47	0	8	....	38281.20	$a^3F'_3-g^3F_2$	407
8........	2611.29	0	25	IV	38283.84	$a^3F'_4-g^3F_4$	407
4........	2605.16	+2	25	IV	38373.92	$a^3F'_3-g^3F_3$	407
12........	2604.88	0	(3)	....	38378.07	$a^3F'_4-g^3D'_3$	408

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
8	2599.91	−1	25	IV	38451.40	$a^3F'_2-g^3F_2$	407
8	2596.60	+1	10	....	38500.40	$a^3F'_3-g^3F_4$	407
12	2594.63	+1	(2)	....	38529.65	$a^3F'_3-g^3D'_2$	408
4	2593.66	+2	(1)	....	38544.04	$a^3F'_2-g^3F_3$	407
8	2590.27	+2	5	....	38594.57	$a^3F'_3-g^3D'_3$	408
12§	2586.26	−1	(3)	....	38654.35	$a^3F'_2-g^3D'_1$	408
8	2583.22	+1	2	....	38699.82	$a^3F'_2-g^3D'_2$	408
8	2580.81	......	5	....	38735.95	....	.....
12	2578.91	+3	(2)	....	38764.48	$a^3F'_2-g^3D'_3$	408
8	2541.92	+1	20	....	39328.54	$a^3F'_4-h^3D'_3$	409
4	2529.86	0	(1)	....	39516.00	$a^3F'_3-h^3D'_2$	409
8	2527.99	+1	5	....	39545.24	$a^3F'_3-h^3D'_3$	409
8	2520.54	0	10	....	39662.11	$a^3F'_2-h^3D'_1$	409
12¶¶	2519.07	+6	(8)	....	39685.24	$a^3F'_2-h^3D'_2$	409
12	2517.14	−1	(1)	....	39715.70	$a^3F'_2-h^3D'_3$	409
8	2504.52	......	3	....	39915.78	....	.....
12	2470.98	−1	(3)	....	40457.53	$a^3F'_4-i^3D'_3$	410
10	2468.60	−1	(1)	....	40496.57	$a^3F'_4-dG'$	411
8	2468.36	0	2	....	40500.50	$a^3F'_3-i^3D'_2$	410
8	2464.98	0	2	....	40556.03	$a^3F'_2-i^3D'_1$	410
12	2458.00	−3	(2)	....	40671.14	$a^3F'_2-i^3D'_2$	410
12	2457.80	−2	(2)	....	40674.44	$a^3F'_3-i^3D'_3$	410
12	2446.12	−1	(2)	....	40868.67	$a^3F'_4-f^3G'_4$	412
8	2440.98	0	10	....	40954.74	$a^3F'_4-f^3G'_5$	412
12	2438.28	−2	(2)	....	41000.10	$a^3F'_3-f^3G'_3$	412
8	2434.09	+1	3	....	41070.65	$a^3F'_4-h^3F_3$	413
8	2433.23	+1	6	....	41085.16	$a^3F'_3-f^3G'_4$	412
12	2431.78	+1	(1)	....	41109.64	$aD-fF$	414
6	2428.36	−1	(1)	....	41167.51	$a^3F'_3-h^3F_2$	413
8	2428.24	+1	2	....	41169.59	$a^3F'_2-f^3G'_3$	412
8	2424.26	0	10	....	41237.17	$a^3F'_4-h^3F_4$	413
8	2421.31	0	10	....	41287.44	$a^3F'_3-h^3F_3$	413
8	2418.37	−1	10	....	41337.60	$a^3F'_2-h^3F_2$	413
6	2411.58	0	(1)	....	41454.04	$a^3F'_3-h^3F_4$	413
8	2411.37	0	2	....	41457.61	$a^3F'_2-h^3F_3$	413
8	2384.52	0	4	....	41924.36	$a^3F'_4-j^3D'_3$	415
6	2380.80	0	(2)	....	41989.81	$a^3F'_4-k^3D'_3$	416
8	2378.15	+1	3	....	42036.65	$a^3F'_3-j^3D'_2$	415
6	2374.59	0	(1)	....	42099.59	$a^3F'_3-k^3D'_2$	416
6	2372.23	−2	(1)	....	42141.47	$a^3F'_3-j^3D'_3$	415
6	2371.95	0	(2)	....	42146.43	$a^3F'_2-j^3D'_1$	415
6	2369.29	0	(1)	....	42193.92	$a^3F'_2-k^3D'_1$	416
6*	2368.57	+1 −1	(1)	....	42206.74	$a^3F'_2-j^3D'_2$ $a^3F'_3-k^3D'_3$	415 416
12	2365.04	0	(1)	....	42269.73	$a^3F'_2-k^3D'_2$	416
6	2314.27	−4	(2)	....	43196.92	$a^3F'_4-i^3F_3$	417
6	2308.88	−2	(2)	....	43297.73	$a^3F'_3-i^3F_2$	417
8	2305.69	0	12	....	43357.59	$a^3F'_4-i^3F_4$	417
8	2302.75	0	10	....	43412.96	$a^3F'_3-i^3F_3$	417
8	2299.86	0	10	....	43467.49	$a^3F'_2-i^3F_2$	417
8	2294.24	+2	3	....	43573.97	$a^3F'_3-i^3F_4$	417
8	2293.78	+2	3	....	43582.71	$a^3F'_2-i^3F_3$	417
8	2280.00	+1	12	....	43846.09	$a^3F'_4-l^3D'_3$	418

TABLE II—*Continued*

Source	Obs. λ (I.A.)	Δλ O−C	Int.	Temp. Class	ν	Designation	Multiplet
8........	2276.75	+ 3	10	....	43908.67	$a^3F'_3-l^3D'_2$	418
8........	2273.33	+ 5	8	....	43974.73	$a^3F'_2-l^3D'_1$	418
6........	2272.63	+ 2	(4)	....	43988.33	$a^3F'_4-g^3G'_5$	419
6........	2272.45	+ 2	(1)	....	43991.82	$a^3F'_3-g^3G'_4$	419
6........	2268.78	0	(2)	....	44062.96	$a^3F'_3-l^3D'_3$	418
6........	2267.98	+ 5	(2)	....	44078.50	$a^3F'_2-l^3D'_2$	418
8........	2264.07	......	5	....	44154.56	....	......
6........	2260.08	+ 3	(1−)	....	44232.52	$a^3F'_2-l^3D'_3$	418
8........	2246.14	......	4	....	44506.98	....	......
6........	2244.69	+ 2	(4)	....	44535.69	$a^3F'_4-j^3F_3$?	420
6*.......	2238.73	{ 0 + 5 }	(4)	....	44654.22	{ $a^3F'_4-j^3F_4$ $a^3F'_3-j^3F_2$	420 420
6........	2238.20	......	(3)	....	44664.79	....	......
6........	2233.79	0	(4)	....	44752.94	$a^3F'_3-j^3F_3$	420
6........	2230.48	+ 1	(4)	....	44819.33	$a^3F'_4-m^3D'_3$	421
6........	2230.18	− 1	(4)	....	44825.36	$a^3F'_2-j^3F_2$	420
6........	2229.67	......	(4)	....	44835.61	....	......
6........	2227.91	− 2	(1+)	....	44871.22	$a^3F'_3-j^3F_4$	420
6........	2226.77	− 2	(3)	....	44894.18	$a^3F'_3-m^3D'_2$	421
6........	2225.11	......	(4)	....	44927.67	....	......
6........	2223.19	0	(4)	....	44966.45	$a^3F'_2-m^3D'_1$	421
6........	2221.48	......	(4)	....	45001.07	....	......
6........	2219.75	0	(3)	....	45036.12	$a^3F'_3-m^3D'_3$	421
6........	2218.38	0	(3)	....	45063.92	$a^3F'_2-m^3D'_2$	421
6........	2211.36	− 3	(1−)	....	45206.94	$a^3F'_2-m^3D'_3$	421
6........	2143.52	......	(3)	....	46637.44	....	......
6........	2126.05	......	(3)	....	47020.76	....	......
6........	2123.50	......	(4)	....	47077.21	....	......
6........	2121.90	......	(3)	....	47112.70	....	......
6........	2117.01	......	(3)	....	47221.49	....	......

* Blend.

† Lines from sun-spot spectrum.

‡ Error in λ corrected.

§ Blend with enhanced line.

‖ May be *Fe* 3705.57.

¶ Measured in low-temperature furnace. "λ 3361.30 measured in high-temperature furnace, a difficult blend" (King).

** Apparently coincides exactly with *Ti*+line.

†† Blend with enhanced line. Enhanced line to violet.

‡‡ Not *Fe* 3125.66; unresolved, but double.

§§ Blend with *Fe* 2981.45 but too strong in furnace for the latter.

¶¶ Too strong; may be a blend.

TABLE II*a*

LINES MASKING *Ti* I LINES

Obs. λ (I.A.)	Element	ν	Designation	Multiplet
6905.94	*Cu*	14476.23	$a^3G'_4-b^3G_3$	37
6743.14	*Ti*	14825.80	$bD-cD'$	....
6292.82	*V*	15886.78	$b^3F'_2-c^3D'_2$	52
5194.04	*Ti*	19247.49	$a^3P'_1-a^5P_2$	116
4848.46	*Ti*	20619.36	$b^3P'_2-g^3D'_3$	142
4667.59	*Ti*	21418.36	$a^3P'_0-c^5D'_1$	162
4535.92	*Ti*	22040.10	$b^3F'_3-d^3F_3$	168
4518.03	*Ti*	22127.36	$a^3H'_6-aI'$	180
4488.32	*Ti*+	22273.84	$a^5F_2-c^5F'_2$	176
4427.10	*Ti*	22581.83	$a^3P'_2-e^3D'_1$	190
4300.55	*Ti*	23246.32	$a^3D_2-i^3D'_2$	208
4290.93	*Ti*	23298.44	$bG-eF$	....
4186.12	*Ti*	23881.76	$b^3P'_1-f^3P_1$	220
4064.22	*Ti*	24598.05	$a^5D'_1-d^5F'_2$	234
4060.27	*Ti*	24621.97	$a^5D'_2-d^5F'_3$	234
4025.13	*Ti*+	24836.93	$a^3D_1-j^3D'_2$	236
3475.45	*Fe*	28765.00	$aG-dG'$	....
3375.69	*Ti*	29615.09	$b^3F'_3-f^3G'_4$	321
3117.89	*Ti*	32063.70	$a^5F_3-e^5D_3$	360
3017.63	*Fe*	33128.96	$aD-e^3P_1$	374
2983.57	*Fe*	33507.15	$a^3P'_0-f^3P_1$	377
2834.75	*Ti*	35266.13	$a^3F'_4-d^5D'_3$	393
2809.15	*Ti*	35587.50	$a^3F'_3-d^5D'_4$	393
2733.58	*Fe*	36571.26	$a^3P'_1-m^3D'_2$	399

NOTES ON TABLE II

1. Bureau of Standards, *Scientific Papers of the Bureau of Standards*, **16**, 54 (No. 372), 1920.
2. Crew, *Astrophysical Journal*, **60**, 108, 1924.
3. Evans, in Kayser, *Handbuch der Spectroscopie*, **6**, 655, 1912.
4. Exner and Haschek, *ibid.*
5. Hasselberg, *ibid.*
6. Kiess, unpublished material.
7. Kilby, *Astrophysical Journal*, **30**, 243, 1909.
8. King, *Mt. Wilson Contr.*, No. 76; *Astrophysical Journal*, **39**, 139, 1914. Also *Mt. Wilson Contr.*, No. 274; *Astrophysical Journal*, **59**, 155, 1924, and unpublished material.
9. Lohse, in Kayser, *Handbuch der Spectroscopie*, **6**, 655, 1912.
10. Miss Moore, unpublished material.
11. Rowland, in Kayser, *Handbuch der Spectroscopie*, **6**, 655, 1912.
12. Russell, unpublished material.

The energy levels and relations of the various terms are shown graphically in Figures 1–3. There are far too many terms to show on a single Bohr-Grotrian diagram, and so the singlet, triplet, and quintet terms are plotted separately. Terms of the same sort, e.g., ^3F or $^3F'$, are plotted on the same vertical line and distinguished by the letters used to designate them in the tables. Those triplet terms which combine with higher singlet terms are, however, plotted on the singlet diagram (Fig. 1), the intercombinations being indicated by dotted lines; and similarly in the other cases. In a few cases, where terms lie close together, the plotted points have been slightly shifted to avoid confusion. These diagrams illustrate in an expressive fashion the great complexity of the spectrum.

4. TEMPERATURE CLASSIFICATION AND ZEEMAN EFFECT

The relation between the temperature classification of the lines and their level of origin is, as usual, very close. It is well known[1] that the appearance of emission lines in the furnace is limited by its temperature—the limit extending steadily toward the ultra-violet as this is increased—while absorption lines may be found, even at low temperatures, as far as the observations can be made.

King's data reproduced in Table II were derived from emission spectra. It is therefore immediately comprehensible why the lines originating (in absorption) in the lowest level a^3F', which are of class I or I A in the visible region, gradually become of class II in the ultra-violet, while the the fainter lines there are of class III, or beyond λ 2200 even of class IV. The lines originating in a^5F', which lies higher by 0.82 volts, are of class II in the visible and class III or IV A in the ultra-violet, and, as Grotrian[2] has found, are much more feebly absorbed by the vapor of the metal at 2000°C.

For the next levels, a^1D (0.90 volts) and a^3P' (1.05), much the same is the case, while the lines coming from b^3F' (1.44 volts) and a^1G (1.50) are divided between classes II and III, even in the visible. There are very few lines of class II belonging to a^5P' (1.73) or a^3G (1.87); the higher levels give, at best, lines of class III; and the highest

[1] King, *Mt. Wilson Contr.*, Nos. 150 and 247; *Astrophysical Journal*, **48**, 13, 1918; **56**, 320, 1922.

[2] *Zeitschrift für Physik*, **25**, 342, 1924.

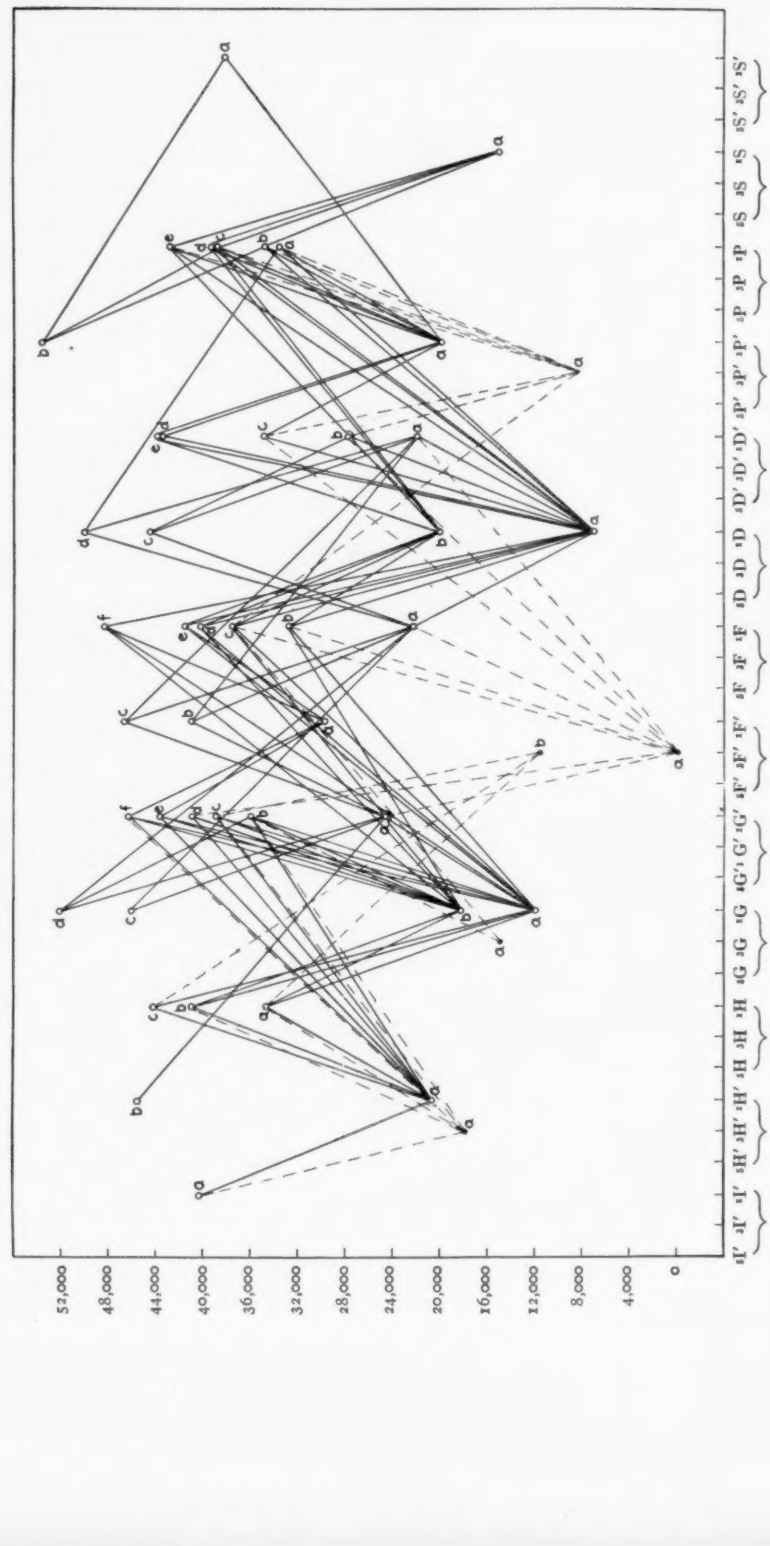


FIG. 1.—*Ti* Singlet combinations

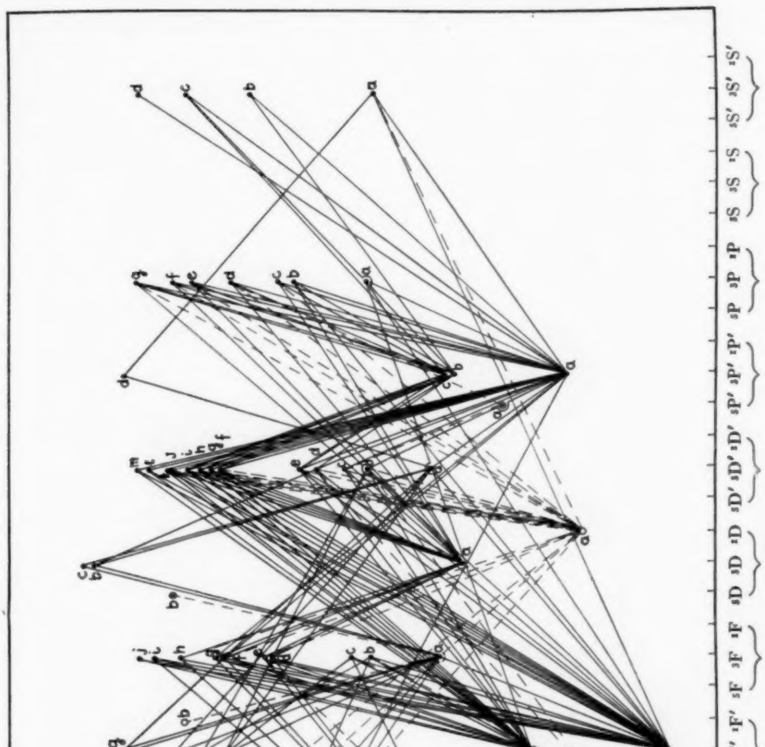


FIG. 2.—*Ti* Triplet combinations

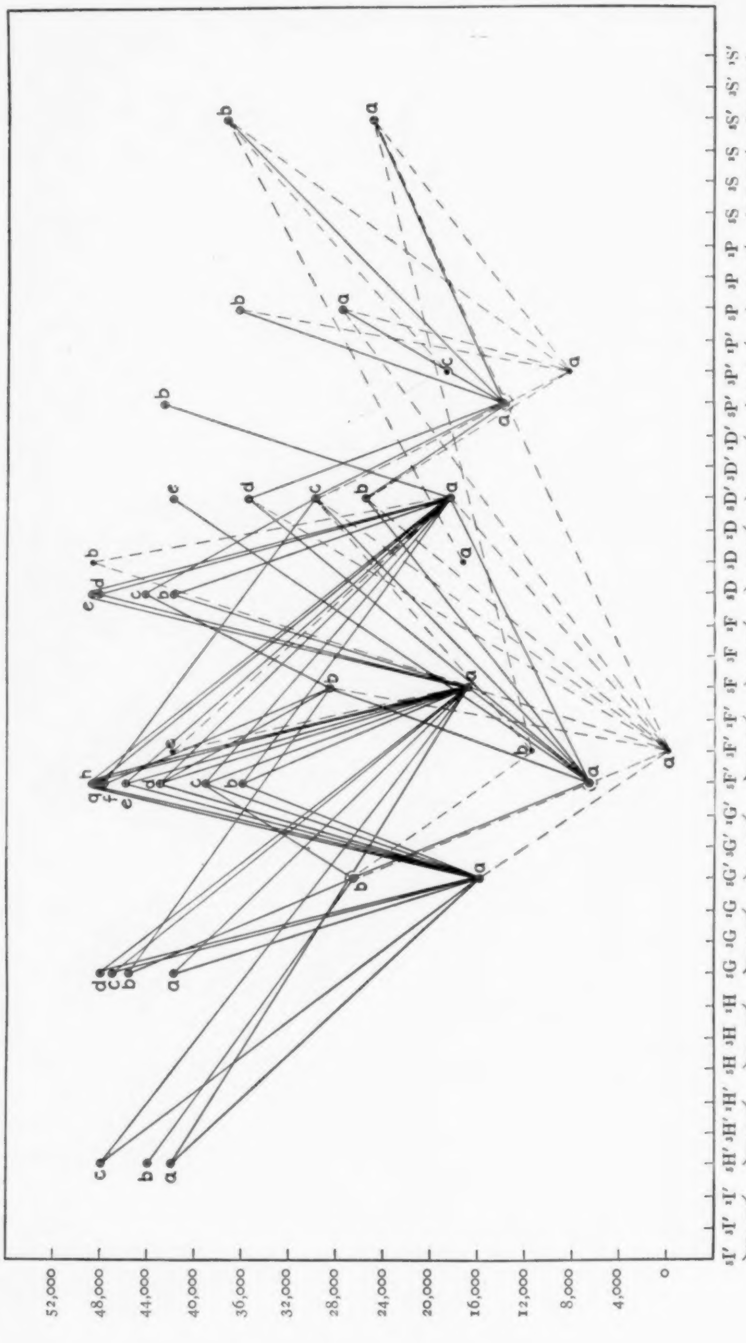


FIG. 3.—*Ti* Quintet combinations

from which transitions upward have been detected, such as b^3D' (3.16) and b^5G' (3.29), give lines of class IV exclusively. The behavior of the titanium lines in sun-spots closely parallels the temperature classification. Those frequenting low atomic levels are greatly strengthened in the spots (especially the weaker lines). This effect diminishes for the lines arising from higher terms, but even those from the highest levels are decidedly intensified.

Extensive measures of the Zeeman effect have been made by King[1] and by Babcock.[2] A comparison of the observed patterns with those calculated by Landé's theory is given in Table III, which is arranged like the similar table for *Ti* II. All combinations between levels of any given sorts, e.g., $^3P_2$ and $^3D_3$, are listed together, no matter which term happens to be the lower, or whether they are primed or unprimed, since in any of these cases they should show the same Zeeman pattern. Babcock's observed data are given to three decimal places; King's, to two. The "blends," given in the last two columns to represent the complex patterns, are derived on the assumption that the center of gravity of the unresolved mass is one-quarter of the way from the strongest component toward the weakest. This rule accords well with the theoretical intensities and with the observations for the majority of the lines. For faint lines, however, or for those in which the pattern is near the limit of resolution, the observed blend is likely to be nearer to the stronger component than the rule would indicate. Such cases are often observed.

[1] *Carnegie Institution of Washington Publications,* No. 153, 1912.

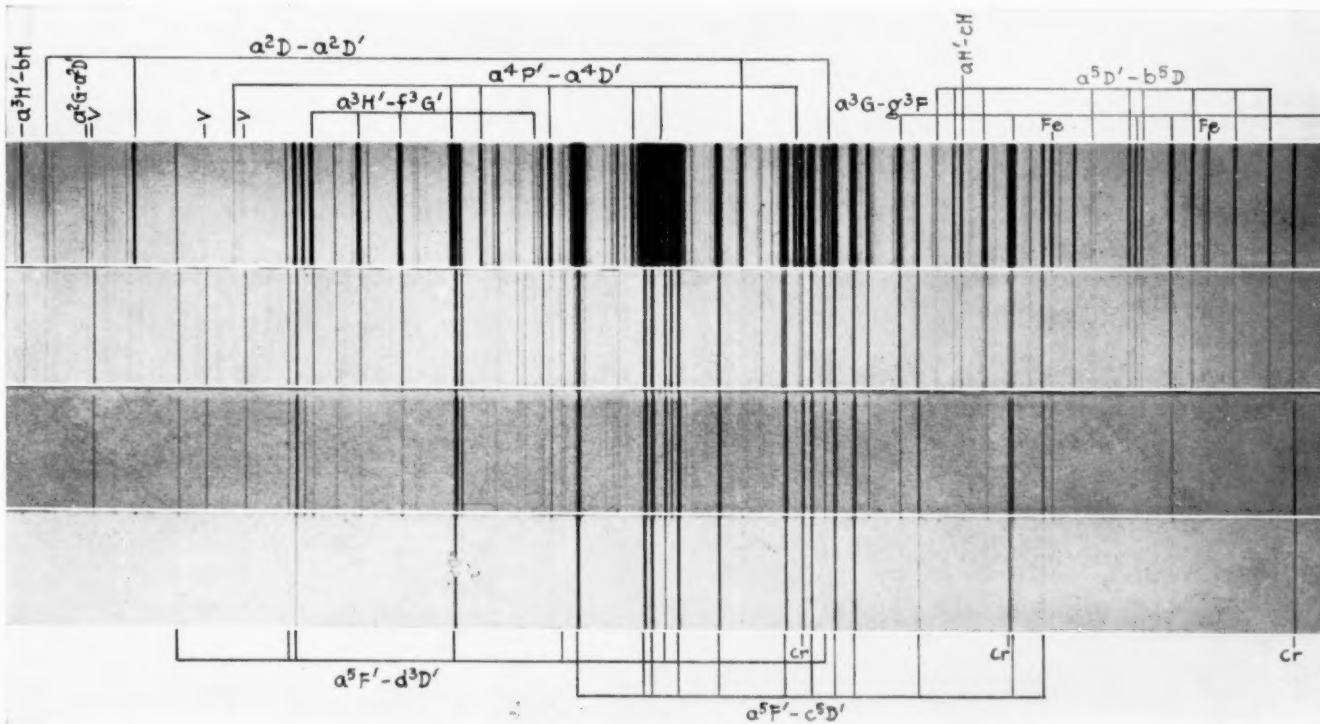
[2] Unpublished material.

TABLE III

OBSERVED AND COMPUTED ZEEMAN EFFECTS IN *Ti* I

Terms	λ	Observed		Theory*		Blend	
		p	*n*	*p*	*n*	*p*	*n*
$^1P-{}^1P'$	5206	0	1.06	0	1.00		
	4372	0	1.00				
$^1P-{}^1D$	3786	0	0.98	0	1.00		
$^1D-{}^1D'$	6743	0	1.02	0	1.00		
	4840	0	1.004				
	4237	0	0.98				
$^1D-{}^1F$	6599	0	1.00	0	1.00		
	5259	0	0.95				
	4975	0	1.054				
	3904	0	0.97				
$^1F-{}^1F'$	5351	0	1.026	0	1.00		
$^1F-{}^1G$	6098	0	0.991	0	1.00		
	4820	0	1.016				
$^1G-{}^1G'$	5644	0	1.021	0	1.00		
	4836	0	0.96				
	4424	0	.95				
	4186	0	0.99				
	3724	0	1.07				
$^1G-{}^1H$	6091	0	1.067	0	1.00		
	5503	0	1.031				
	4427	0	1.000				
	4393	0	1.03				
	4369	0	0.98				
	[illegible]26	0	0.98				
$^1H-{}^1H'$	4938	0	1.061	0	1.00		
	4278	0	1.02				
$^1H-{}^1I$	5120	0	1.024	0	1.00		
$^3F_3-{}^1D_2$	4562	0	1.25	**0.00**	0.92	0	1.17
				.08	....		
				.17	1.17		
					1.25		
$^3F_4-{}^1G_4$	4112	0.86	$1.09W_2$	.25	0.25	0.81	1.12W
				.50	....		
				0.75	**1.00**		
				1.00	**1.25**		
					....		
					2.00		

PLATE VII



ARC AND FURNACE SPECTRUM OF Ti λ4347 TO λ4251

Multiplets of the arc and spark spectra are indicated, including singlets, doublets, triplets, quartets, quintets, and various inter-system combinations.

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	n	p	n	p	n
$^3G_3-{}^1F_3$	4440	0.52	0.84w$_1$	0.25	0.25	0.62	0.87w
				.50	.50		
				.75	**0.75**		
					1.00		
					1.25		
					1.50		
$^3H_4-{}^1G_4$	5565	.561	.920	.20	0.20	0.65	0.90
	4778	0.491	0.943	.40	....		
				.60	**0.80**		
				.80	**1.00**		
					....		
					1.60		
$^3H_4-{}^1H_5$	5999	w$_2$	1.467w$_1$	**.00**	0.20	ow	1.40w
	4346	w$_2$	1.47w$_1$	.20	....		
				....	1.60		
				.80	**1.80**		
$^3S_1-{}^3P_0$	6064	0	1.954	.00	2.00		
$^3S_1-{}^3P_1$	6085	0.501	1.496	.50	1.50		
			1.985		2.00		
$^3S_1-{}^3P_2$	6126	**0**	**0.998**	**.00**	**1.00**	ow	1.25w
		0.497	1.490	0.50	1.50		
	3725	w$_1$	1.15		2.00		
$^3P_0-{}^3P_1'$	4065	0	1.47	0	1.50		
	4055	0	1.47				
$^3P_1-{}^3P_1'$	4064	0	1.47	0	1.50		
$^3P_1-{}^3P_2'$	5903†	0	1.491	0	1.50		
	5880†	0	1.425				
	4323	0	1.52				
	4082	0	1.47				
	4060	0	1.47				
$^3P_2-{}^3P_2'$	5918	0	1.489	0	1.50		
	5429	0	1.542				
	4078	0	1.46				
$^3P_0-{}^3D_1$	5922	0	0.492	0.00	0.50		
	5069	0	.56				
	4796	0	.52w$_1$				
	4710	0	0.506				
$^3P_1-{}^3D_1$	5941	0.990	0.489	1.00	0.50		
			1.527		1.50		
	4797	1.03	0.58				
			1.58				
	4722	1.07	0.62				
			1.53				
	4405	0.99	w$_2$				

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	n	p	n	p	n
$^3P_1-{}^3D_2$	5899	0	1.127	**0.00**	**0.83**	0w	1.00w
	5062	w_1	0.99	.33	1.17		
	4792	w_3	0.918w_2		1.50		
	4698	w_2	1.02w_2				
$^3P_2-{}^3D_2$	5937	0.39	1.46w_2	.33	0.83	0.59w	1.33w
	4723	0.62	1.24w_2	**.67**	**1.17**		
					1.50		
					1.83		
$^3P_2-{}^3D_3$	5866	0	1.169w_2	**.00**	**1.00**	0w	1.17w
	5295	w_1	1.23w_1	.17	1.17		
	5052	w_1	1.08	.33	1.34		
	4805	w_1	1.08		1.50		
	4691	w_1	1.23		1.67		
	4422		1.18				
$^3P_2-{}^3F_2$	3921†	–?	0.00	0.83	−0.17	0.93‡	−0.27
			0.78	**1.67**	**0.67**	**1.87**	**0.67**
			1.68		**1.50**		**1.60**
			2.64		2.33		2.53
$^3P_2-{}^3F_3$	3947†	w_2	0.39w_2	**0.00**	**0.25**	**0.00‡**	**0.05**
				.42	0.67	0.52	0.56
				.83	1.08	1.04	**1.08**
					1.50		1.60
					1.92		2.12
$^3D_1-{}^3D_1'$	4880	0	.51	.00	0.50		
	4696	0	.54				
	4311	w_1	0.49				
$^3D_2-{}^3D_2'$	4864	0	1.14	.00	1.17		
$^3D_3-{}^3D_3'$	4848	0	1.35	.00	1.33		
	4710	0	1.333				
	4035	0	1.33				
$^3D_1-{}^3F_2$	6318	0	0.734	**.00**	0.50	0	0.75
	5514	0	.73	.17	.67		
	5087	0	.78		**.83**		
	4928	0	.732				
	4171	0	.74				
	3948	0	.73				
$^3D_2-{}^3F_2$	4997	1.02	?	0.50	.17	0.87w	.92w
	3929†	1.16	.00	**1.00**	**0.67**	0.68§	−0.02
			0.75		**1.17**	**1.37**	**0.67**
			1.46		1.67		**1.35**
			2.10				2.03

TABLE III—*Continued*

Terms	λ	Observed *p*	Observed *n*	Theory* *p*	Theory* *n*	Blend *p*	Blend *n*
$^3D_2-{}^3F_3$	6336	0	0.936	**0.00**	**0.92**	0	1.00w
	5514	0	0.94	.08	1.00		
	5113	0	1.01	.17	....		
	5039	0	0.993		1.25		
	4919	0	.988			**0.00**§	**0.55**
	4733	0	.975			.27	0.81
	4159	0	.93			.54	....
	3956†	0	0.90				1.62
$^3D_3-{}^3F_3$	5009	0.68	?	.25	0.58	0.62w	1.21w
	3924	0.65	$1.16w_2$	.50	....		
				.75	**1.08**		
					1.33		
					....		
					1.83		
$^3D_3-{}^3F_4$	6366	0	1.016	**.00**	**1.00**	0	1.12w
	5648	0	1.160	.08	1.08		
	5512	0	1.15	.17	....		
	5145	0	1.14	.25	1.50		
	5064	0	1.119				
	4921	0	1.088				
	4731	0	1.094				
	4150	0	1.09				
	3958	0	1.12				
$^3F_2-{}^3F'_2$	6546	0	0.673	.00	0.67		
	5488	0	.676				
	5173	0	.667				
	4518	0	.66				
	4453	0	.649				
	3981†	0	.73				
	3729	0	0.63				
$^3F_2-{}^3F'_3$	6508	w_3	$1.91w_3$	**.00**	.25	0w	1.50 w
	5219	w_2	1.20	.42	0.67		
			1.48	.83	1.08		
			1.83		1.50		
	5147	w_3	$1.86w_2$		**1.92**		
	4474	w_3	$1.56w_1$				
	4008	w_2	$1.32w_2$				
	3962†	w_2	$1.80w_2$				
	3753	w_2	1.63				
$^3F_3-{}^3F'_3$	6554	0	1.046	0.00	1.08		
	5481	0	1.121				
	5192	0	1.080				
	4455	0	1.106				
	3989	0	1.06				
	3741	0	1.09				

TABLE III—*Continued*

Terms	λ	Observed p	Observed n	Theory* p	Theory* n	Blend p	Blend n
$^3F_3-^3F'_4$	6497	0	1.76	**0.00**	0.75	0w	1.50w
	5252	w_2	1.52w_2	.17	0.92		
	5152	w_1	1.55w_1	.33	....		
	4482	w_2	1.52w_1	.50	1.58		
	4430	w_2	1.46w_1		**1.75**		
	4024	w_1	1.49w_1				
	3964	w_1	1.40w_1				
	3771	w_1	1.54				
	3722†	w_1	0.64				
$^3F_4-^3F'_4$	6556	0	1.232	.00	1.25		
	5477	0	1.270				
	5210	0	1.250				
	4559	0	1.32				
	4457	0	1.242				
	3998†	0	1.06				
	3752	0	1.21				
$^3F_2-^3G_3$	6261	0	0.833	**.00**	0.58	0	0.83
	6221	0	.801	.08	.67		
	5390	0	.794	.17	.75		
	5297	0	.843		.83		
	5038	0	.833		**.92**		
	4656	0	.83				
	4433	0	.830				
	4282	0	.82				
$^3F_3-^3G_3$	6303	0.86	.87w_3	.33	.08	0.83w	0.91w
	5066	?	.97	0.67	.42		
				1.00	**0.75**		
					1.08		
					1.42		
					1.75		
$^3F_3-^3G_4$	6258	0	.987	**0.00**	**0.95**	0	1.00
	6220	0	0.987	.03	0.98		
	5397	0	1.010	.07	....		
	5283	0	1.000	.10	1.12		
	5036	0	1.004		1.15		
	4667	0	0.98				
	4426	0	1.004				
	4274	0	0.97				
$^3F_4-^3G_4$	6312	0.658	1.272	.20	0.45	0.65w	1.15w
	5071	0.66	1.12w_2	.40	....		
	4404‖	0	1.00	.60	**1.05**		
				0.80	**1.25**		
					....		
					1.85		

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	n	p	n	p	n
$^3F_4 - {}^3G_5$	6258	0	1.098	**0.00**	**1.00**	0	1.10
	6215	0	1.057	.05	1.05		
	5474	0	1.061	.10	....		
	5409	0	1.107	.15	1.35		
	5265	0	1.067	.20	1.40		
	5035	0	1.101				
	4681	0	1.12				
	4417	0	1.087				
	4263	0	1.12				
$^3G_3 - {}^3G'_3$	6146	0	0.750	.00	0.75		
	4453¶	0.175	0.760				
$^3G_3 - {}^3G'_4$	4463¶	w_2	1.57w_1	**.00**	0.15	0w	1.50w
	4441	w_2	1.28w_1	.30	....		
				.60	1.65		
				.90	**1.95**		
					....		
$^3G_4 - {}^3G'_4$	6121	0	1.02	.00	1.05		
	4450	0	1.057				
$^3G_4 - {}^3G'_5$	4463¶	w_1	1.57	**.00**	0.60	0w	1.50w
	4436	w_2	1.45w_1	.15	....		
				....	1.65		
				.60	**1.80**		
					....		
$^3G_5 - {}^3G'_5$	6092	0	1.185	.00	1.20		
	4449	0	1.212				
$^3G_3 - {}^3H_4$	5978	0	0.874	**.00**	0.65	0	0.87
	4913	0	0.879	.05	....		
	4321	0	1.02	....	.90		
	4122	0	0.94	.15	**.95**		
$^3G_4 - {}^3H_4$	4925	0.92	?	.25	....	0.75w	0.92w
				.50	**0.80**		
				0.75	**1.05**		
				1.00	....		
$^3G_4 - {}^3H_5$	5965	0	1.000	**0.00**	**0.97**	0	1.00
	4899	0	1.007	.02	0.98		
	4325	0	1.002	....	1.00		
	4123	0	0.95	.07	....		
					1.10		
$^3G_5 - {}^3H_5$	4915	0.59	1.05w_2	.17	....	0.67w	1.12w
				....	**1.03**		
				.67	**1.20**		
				0.83	....		

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	*n*	*p*	*n*	*p*	*n*
$^3G_5-^3H_6$	5953	o	1.088	**0.00**	**1.00**	0.00	1.08
	4885	o	1.098	.03	1.03		
	4318	o	1.054	....	....		
	4127	o	1.05	.17	1.33		
$^3H_4-^3H'_4$	5740	o	0.805	.00	0.80		
	4742	o	0.840				
$^3H_5-^3H'_5$	5739	o	1.034	.00	1.03		
	4758	o	1.023				
$^3H_5-^3H'_6$	4769	w_2	$1.57w_2$	**.00**	0.50	ow	1.50w
				.13	....		
				....	1.70		
				.67	**1.83**		
$^3H_6-^3H'_6$	5715	o	1.17	.00	1.17		
	4759	o	1.181				
$^3H_4-^3I_5$	4868	o	0.821	**.00**	0.70	o	0.90
				.03	.73		
				....	....		
				.10	.93		
				.13	**.97**		
$^3H_5-^3I_6$	4870	o	1.010	**.00**	**.976**	o	1.00
				.010	0.986		
				....	....		
				.038	1.062		
				.048	1.072		
$^3H_6-^3I_7$	4856	o	1.078	**.00**	**1.00**	o	1.07
				.02	1.02		
				....	....		
				.12	1.26		
				.14	1.29		
$^3P_2-^5D_3$	4675	o	1.42	0.00	1.50		
$^3F_2-^5S_2$	3982†	2.19	**0.57**	1.33	−0.67	0.17**	−0.50
			1.83	**2.66**	**0.67**	**2.33**	**0.67**
			3.03		**2.00**		**1.83**
					3.33		3.00
$^3F_3-^5S_2$	4009†	?	0.33	**0.00**	**−0.75**	**0.00****	**−0.42**
				0.92	0.17	0.75	0.33
				1.83	1.08	1.50	1.08
					2.00		1.83
					2.92		2.58

** $g=1.83$

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	n	p	n	p	n
$^3F_4-^5D_4$	3914	0.83	$1.41w_2$	0.25 .50 0.75 **1.00**	0.50 .... **1.25** **1.50** 2.25	0.81w	1.38w
$^3F_4-^5D_3$	5490	w_3	$0.80w_2$	**0.00** .25 .50 .75	**0.50** 0.75 .... 2.00	w	0.87w
$^5F_3-^3D_2$	4326	0	1.314	**.00** .08 .17	1.08 .... 1.33 **1.42**	0	1.33
$^5F_3-^3D_3$	4299¶	w_1	1.18	.08 .17 **.25**	1.08 .... **1.25** **1.33** 1.50	w	1.29w
$^5F_4-^3D_3$	4314	0	1.372	**.00** .02 .... .05	1.30 .... 1.38 **1.40**	0	1.37
$^5F_2-^3F_3'$	4926	0	1.27	**.00** .08 .17	0.92 .... 1.17 **1.25**	0	1.17
$^5F_4-^3G_5$	4291¶	0	0.77	**.00** .15 .60	**0.60** 0.75 1.80	0w	0.90w
$^5F_5-^3G_5$	4781	$0.84w_2$	w_3	.20 .40 .60 0.80 **1.00**	0.40 .... **1.20** **1.40** 2.20	0.80w	1.30w
$^5S_2-^5P_1$	4276	w_2	$1.49w_1$	**0.00** .50	**1.50** 2.00 2.50	w	1.75w
$^5S_2-^5P_2$	4284	w_1	1.89	.16 **0.33**	1.67 **1.83** **2.00** 2.17	w	1.91w

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	n	p	n	p	n
$^5S_2-^5P_3$	4299¶	w_2	1.43	**0.00**	**1.00**		
				.33	1.33		
				.67	1.67		
					2.00		
					2.33		
$^5P_1-^5P'_1$	4479	0	2.53	.00	2.50		
$^5P_1-^5P'_2$	4489	**0.00**	**1.150**	**.00**	**1.17**		
		.653	1.82	.67	1.83		
			2.61		2.50		
	4471	**.00**	**1.151**				
		0.654	1.825				
			2.54				
$^5P_2-^5P'_2$	4480	0	1.87	.00	1.83		
$^5P_2-^5P'_3$	4496	0	1.50	**.00**	**1.33**	0w	1.50w
	4465	w_1	$1.48w_1$	.17	1.50		
				0.33	....		
					2.00		
$^5P_3-^5P'_3$	4481	0	1.665	0	1.67		
$^5P_1-^5D_0$	4645	0	2.50	0	2.50		
$^5P_1-^5D_1$	4639¶	1.01	1.52	1.00	1.50		
			2.46		2.50		
$^5P_1-^5D_2$	4629	**0.00**	**0.50**	**0.00**	**0.50**		
		1.03	1.53	1.00	1.50		
			2.50		2.50		
$^5P_2-^5D_1$	4650	w_2	$2.08w_1$	**0.00**	1.50	w	2.00w
				.33	1.83		
					2.16		
$^5P_2-^5D_2$	4639¶	0.64	$1.69w_3$	.33	1.17	0.59w	1.67w
				.67	**1.50**		
					1.83		
					2.16		
$^5P_2-^5D_3$	4623	w_3	$1.09w_2$	**.00**	**0.83**	w	1.17w
				.33	1.17		
				.67	....		
					2.16		
$^5P_3-^5D_3$	4639¶	?	1.56	.17	1.17	0.42w	1.58w
				.33	....		
					1.50		
				0.50	**1.67**		
					....		
					2.00		

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	n	p	n	p	n
$^5P_3-{}^5D_4$	4617 4137	w_2 0	$1.16w_1$ 1.31	0.00 .17 .33 0.50	1.00 1.17 .... 2.00	w	1.25 w
$^5D_3-{}^5D'_3$	4261†	w_1	$1.09w_1$	0	1.50		
$^5D_4-{}^5D'_4$	4256†	0	$1.34w_1$	0	1.50		
$^5D_0-{}^5F_1$	5713 4295	0 0	0 0	0.00	0.00		
$^5D_1-{}^5F_1$	5720 4290	1.65 1.48	0.00 1.77 0.00 1.47	1.50	0.00 1.50		
$^5D_1-{}^5F_2$	5702 4298	w_2 0.00 .48	$0.68w_3$ .48 .97	0.00 .50	0.50 1.00 1.50	w	0.75w
$^5D_2-{}^5F_1$	4281	0.00 1.50	0.00 1.48 3.00	0.00 1.50	0.00 1.50 3.00		
$^5D_2-{}^5F_2$	5716 4289	0.94 .47 0.96	$1.26w_3$ 0.48 1.02 1.48 1.96	0.50 1.00	0.50 1.00 1.50 2.00	0.87w	1.25w
$^5D_2-{}^5F_3$	5689 4300	w_2 w_2	$0.98w_2$ $0.88w_1$	0.00 .25 .50	0.75 1.00 .... 1.75	0.0w	1.00w
$^5D_3-{}^5F_3$	5711 4286	0.68 0.55	1.49 $1.34w_2$	.25 .50 .75	0.75 .... 1.25 1.50 .... 2.00	0.62w	1.37w
$^5D_3-{}^5F_4$	5675 4301	w_1 w_1	$1.08w_1$ $1.182w_1$	.00 .15 .... .45	0.90 1.05 .... 1.80	ow	1.12w
$^5D_4-{}^5F_3$	4272	w_3	$1.22w_3$	.00 .25 .... 0.75	0.75 .... 2.00 2.25	ow	1.88?

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	n	p	n	p	n
$^5D_4-{}^5F_4$	5708	0.70	$1.59w_2$	0.15	0.90	0.49w	1.42w
	4287	0.49	$1.40w_2$	....	....		
				.45	**1.35**		
				.60	**1.50**		
					....		
					1.95		
$^5D_4-{}^5F_5$	5662	w_1	$1.30w_1$	**.00**	**1.00**	ow	1.20w
	4305	w_2	$1.21w_1$	.10	1.10		
				....	....		
				.40	1.80		
$^5F_1-{}^5F_1'$	5222	o	0.00	.00	0.00		
	4536	o	.00				
$^5F_1-{}^5F_2'$	5238†	w_1	$.85w_1$	**0.00**	0.00		
	4544	**0.00**	0.00	1.00	1.00		
		1.00	1.00		**2.00**		
			1.98				
	4527	**0.00**	0.00				
		1.002	0.992				
			2.000				
$^5F_2-{}^5F_2'$	5223†	o	1.097	0.00	1.00		
	4535	o	0.982				
$^5F_2-{}^5F_3'$	5247†	w_2	$1.72w_2$	**.00**	0.75	ow	1.50w
	5201†	w_1	$0.86w_1$	.25	....		
	4548	w_2	$1.66w_1$	.50	1.50		
	4522	w_2	$1.51w_1$		**1.75**		
$^5F_3-{}^5F_3'$	5224¶	o	1.265	.00	1.25		
	4535	o	1.241				
$^5F_3-{}^5F_4'$	5255	w_1	$1.44w_1$	**.00**	1.05	ow	1.50w
	4552	w_1	1.51	.10	....		
	4518	w_1	1.50	....	1.55		
				.30	**1.65**		
$^5F_4-{}^5F_4'$	5224¶	o	1.375	.00	1.35		
	4534	o	1.326				
$^5F_4-{}^5F_5'$	5263	o	$1.55w_1$	**.00**	1.20	o	1.50
	4555	o	1.50	.05	....		
	4512	o	1.501	....	1.55		
				.20	**1.60**		
$^5F_5-{}^5F_5'$	5224¶	o	1.425	.00	1.40		
	4533	o	1.376				
$^5F_1-{}^5G_2$	5014¶	0.00	.53	**.00**	0.00	ow	0.50w
	4978	w_1	$0.59w_1$	0.33	.33		
					0.67		

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	*n*	*p*	*n*	*p*	*n*
$^5F_2-^5G_2$	5024	0.65	**0.341**	0.67	−0.33		
		1.348	1.050	**1.33**	**0.33**		
			1.741		**1.00**		
					1.67		
$^5F_2-^5G_3$	{5007	0.00	0.838	**0.00**	**0.75**	0	0.83
	4989	.00	0.836	.08	0.83		
				.17	....		
					1.08		
$^5F_3-^5G_3$	5022	0.90w_1	1.13w_3	.33	0.25	0.83w	1.08w
				0.67	....		
				1.00	**0.92**		
					1.25		
					....		
					1.92		
$^5F_3-^5G_4$	{5001	w_1	0.99	**0.00**	**0.85**	0	1.01w
	4999	0	1.01	.10	0.95		
				....	....		
				.30	1.45		
$^5F_4-^5G_4$	5020	0.711	1.202w_3	.20	0.55	0.65w	1.25w
				....			
				.60	**1.15**		
				.80	**1.35**		
					....		
					1.95		
$^5F_4-^5G_5$	{5013	0	1.072	**.00**	**0.93**	0	1.10w
	4991	0	1.151	.08	1.02		
	4026†	0	0.83	....	....		
				.33	1.60		
$^5F_5-^5G_5$	5016	0.559	1.308	.13	0.73	0.53	1.33
				....	....		
				.53	**1.27**		
				.67	**1.40**		
					....		
					1.93		
$^5F_5-^5G_6$	{5025	0	1.115	**.00**	**1.00**	0	**1.17**
	4981	0	1.196	.07	1.07		
	4030†	w_1	0.92w_1	....	....		
				.33	1.67		
$^5G_3-^5G'_4$	3868	w_1	1.40	**.00**	0.45	0w	**1.50w**
				.23	....		
				....	1.62		
				0.70	**1.85**		

TABLE III—*Continued*

Terms	λ	Observed		Theory*		Blend	
		p	*n*	*p*	*n*	*p*	*n*
$^5G_4-^5G'_5$......	3875	o	1.32	**0.00**	0.80	ow	1.50w
				.12	....		
				....	1.62		
				.47	**1.73**		
$^5G_5-^5G'_6$......	3882¶	o	1.32	**.00**	1.00	o	1.50w
				.07	....		
				....	1.60		
				.33	**1.67**		
$^5G_3-^5H_4$......	{5766	o	0.917	**.00**	**0.85**	o	0.87
	{3853	w₁	1.10	.02	.87		
				....	....		
				.05	.95		
$^5G_4-^5H_5$......	{5774	o	1.028	**.00**	**.90**	o	1.00
	{3858	w₁	1.14	.05	0.95		
				....	....		
				.20	1.30		
$^5G_5-^5H_5$......	3882¶	w₂	1.62w₁	.17	0.43	0.67w	1.19w
				....	....		
				.67	**1.10**		
				.83	**1.27**		
					....		
					1.93		
$^5G_5-^5H_6$......	{5785	o	1.097	**.00**	**0.95**	o	1.08
	{3866	o	1.16	.05	1.01		
				....	....		
				.26	1.48		
$^5G_6-^5H_6$......	3895	w₁	1.25	.12	0.62	0.56w	1.28w
				....	....		
				.60	**1.22**		
				.71	**1.33**		
					....		
					1.93		
$^5G_6-^5H_7$......	{5804	o	1.157	**.00**	**1.00**	o	1.14
	{3882¶	o	1.13	.05	1.05		
				....	....		
				0.29	1.57		

* The theoretical patterns given in the fifth and sixth columns and the computed blends in the last two columns apply equally to all of the lines having the same multiplet designation as indicated in the first column.

† g value abnormal.

‡ g = 1.60.

§ g = 1.35.

‖ Blend.

¶ Measures disturbed by components of neighboring line.

** g = 1.83.

A similar comparison has been made by Dr. and Mrs. Kiess for many of the lines identified by them.

For the great majority of the more than 300 lines included in Table III, the Zeeman effect appears to be in full agreement with Landé's theory. For a few lines marked with a dagger (†) in the table the patterns appear to be abnormal. If these are set aside for the moment and means are taken for the separations of the stronger lines, the 28 singlet lines give a mean separation of 1.007 and an average deviation, without regard to sign, of ± 0.029 from the theoretical value 1.00; further, 9 lines belonging to $^3P^3P'$ groups give a

TABLE IV

MEAN ZEEMAN SEPARATIONS—TRIPLET SYSTEM

Type	PD			DD′			DF		
No.	(6)	(4)	(4)	(3)	(1)	(3)	(9)	(7)	(6)
Obs.	1.16	1.01	0.52	1.34	1.14	0.51	1.11	0.96	0.74
Comp.	1.17	1.00	0.50	1.33	1.17	0.50	1.12	1.00	0.75
Type	FF′			FG			GG′		
No.	(6)	(4)	(4)	(9)	(8)	(8)	(2)	(2)	(2)
Obs.	1.25	1.08	0.66	1.09	0.99	0.82	1.20	1.04	0.75
Comp.	1.25	1.08	0.67	1.10	1.00	0.83	1.20	1.05	0.75
Type	GH			HH′			HI		
No.	(4)	(4)	(4)	(2)	(2)	(2)	(1)	(1)	(1)
Obs.	1.08	0.99	0.93	1.18	1.03	0.82	1.08	1.01	0.82
Comp.	1.08	1.00	0.87	1.17	1.03	0.80	1.07	1.00	0.90

mean separation of 1.485 instead of 1.500. For the leading components of the principal multiplets of the triplet system, observation and theory compare as indicated in Table IV. The components are arranged in order of decreasing inner-quantum number in each multiplet. For the skew-symmetrical groups the separations should be equal to Landé's g's, and they are so with remarkable accuracy. For the other multiplets the agreement with the values calculated from the table for blending, given above, suffices to show that, on the average, this rule gives a very good approximation to the facts. All the g's for the triplet system as far as the H terms, and many of those for the quintets, could be determined from these data alone.

A few terms exhibit abnormal g values. The most notable are

a^3P_2, for which g appears to be about 1.60 instead of 1.50; b^3D_2, 1.35 instead of 1.17; and a^5S_2, 1.89 instead of 2.00. These terms have the same inner-quantum number and very nearly the same energy level, and it appears probable that they perturb one another in some way, as in the case studied in calcium by Back.[1] The first and last of these terms give abnormally strong combinations with a^3F. There is some evidence that some of the components of b^3F, which also lies at very nearly the same level, are also affected. A detailed study of these peculiarities would not be difficult, as the Zeeman patterns are very open, and might be of considerable theoretical interest.

Some of the high-lying quintet lines, such as b^5D and a^5G, appear also to have abnormal g's, and for these, too, the intensities in the multiplets are abnormal.

5. THEORETICAL INTERPRETATION OF THE OBSERVED TERMS: THE QUINTET SYSTEM

The terms which are to be expected in the spectrum of *Ti* I, according to Hund's theory,[2] are listed in Table V, together with the observed terms which are believed to represent them. They are grouped in accordance with the electronic configurations which produce them and the terms in *Ti* II to which they go as limits. These all belong to the low even set, and their assignment to the various configurations appears to be free from uncertainty. The first column gives the configuration; the second, the limit when the last-mentioned electron is removed; the third, the terms which are theoretically to be expected, and the fourth, those observed terms which have been identified with them. One term, which is predicted but not observed in *Ti* II, is put in brackets.

For a number of the higher configurations, only the terms which arise from the lowest terms of *Ti* II are listed, since none of the numerous terms corresponding to other limits have been identified. For the last entry the limit is taken to be the term in *Ti* III obtained by removing the two 4p electrons.

The reasons for assigning the various observed terms to the given configurations may now be given.

[1] *Zeitschrift für Physik*, **33**, 579, 1925.

[2] *Linienspektren*, pp. 184 ff.

TABLE V

PREDICTED AND OBSERVED TERMS IN *Ti* I

Configuration	Limit *Ti* II	Predicted Terms	Observed Terms
$(3d)^2\ (4s)^2$...	a^4F', a^2F'	$^3F'$	a^3F'
	b^4P', b^2P'	$^3P'$	a^3P'
	a^2S	^1S	a^1S
	a^2D	^1D	a^1D
	b^2G	^1G	a^1G
$(3d)^3\ 4s$.....	b^4F'	$^5F'$; $^3F'$	a^5F'; b^3F'
	a^4P'	$^5P'$; $^3P'$	a^5P'; c^3P'
	a^2P'	$^3P'$; $^1P'$	b^3P'; a^1P'
	b^2D	^3D; ^1D	a^3D; b^1D
	b^2F'	$^3F'$; $^1F'$	—; a^1F'
	a^2G	^3G; ^1G	a^3G; b^1G
	a^2H'	$^3H'$; $^1H'$	a^3H'; a^1H'
	(^2D)	^3D; ^1D	—; —
$(3d)^4$........	....	^5D; $^3P'$ $^3F'$	—; —
		$^3P'$ ^3D $^3F'$ ^3G $^3H'$	— b^3D? — b^3G —
		^1S ^1D ^1G	—; —
		^1S ^1D $^1F'$ ^1G ^1I	—; —
$(3d)\ (4s)^2\ 4p$.	c^2D	^3P, $^3D'$ ^3F; ^1P, $^1D'$, ^1F	g^3P e^3D i^3F; — — —
$(3d)^2\ 4s\ 4p$...	a^4F'	$^5D'$ ^5F $^5G'$; $^3D'$ ^3F $^3G'$	a^5D' a^5F, a^5G'; b^3D' b^3F c^3G'
	b^4P'	$^5S'$ ^5P $^5D'$; $^3S'$ ^3P $^3D'$	a^5S' a^5P b^5D'; b^3S' c^3P f^3D'
	a^2S	^3P ^1P	— — —; e^1P?
	b^2P'	$^3S'$ ^3P $^3D'$; $^1S'$ ^1P $^1D'$	a^3S' a^3P c^3D'; — b^1P c^1D'
	a^2D	^3P $^3D'$ ^3F; ^1P $^1D'$ ^1F	b^3P e^3D' d^3F; a^1P, b^1D' c^1F
	a^2F'	$^3D'$ ^3F $^3G'$; $^1D'$ ^1F $^1G'$	a^3D' a^3F a^3G'; a^1D' a^1F a^1G'
	a^2G	^3F $^3G'$ ^3H; ^1F $^1G'$ ^1H	e^3F d^3G' a^3H; e^1F c^1G' c^1H
$(3d)^2\ 4s\ 5p$...	a^4F'	$^5D'$ ^5F $^5G'$; etc.	e^5D' — —; — — —
$(3d)^3\ 4p$.....	b^4F'	$^5D'$ ^5F $^5G'$; $^3D'$ ^3F $^3G'$	c^5D' b^5F b^5G'; d^3D' c^3F b^3G'
	a^4P'	$^5S'$ ^5P $^5D'$; $^3S'$ ^3P $^3D'$	b^5S' b^5P d^5D'; c^3S' d^3P h^3D'
	a^2P'	$^3S'$ ^3P $^3D'$; $^1S'$ ^1P $^1D'$	d^3S' f^3P i^3D'; a^1S' d^1P d^1D'
	b^2D'	^3P $^3D'$ ^3F; ^1P $^1D'$ ^1F	e^3P j^3D' f^3F; c^1P e^1D' $d\ ^1F$
	b^2F'	$^3D'$ ^3F $^3G'$; $^1D'$ ^1F $^1G'$	g^3D' h^3F, —; — f^1F? f^1G'?
	a^2G	^3F $^3G'$ ^3H; ^1F $^1G'$ ^1H	g^3F e^3G' b^3H; b^1F b^1G' a^1H
	a^2H'	$^3G'$ ^3H $^3I'$; $^1G'$ ^1H $^1I'$	f^3G c^3H a^3I'; e^1G' b^1H a^1I'
	(^2D)	^3P $^3D'$ ^3F; ^1P $^1D'$ ^1F	— — — ; — — — —
$(3d)^2\ 4s \cdot 5s$...	a^4F'	$^5F'$; $^3F'$	b^5F'; c^3F'
	b^4P'	$^5P'$; $^3P'$	—; d^3P'
	a^2S	^3S; ^1S	—; —
	b^2P'	$^3P'$; $^1P'$	—; —
	a^2D	^3D; ^1D	—; c^1D
	a^2F'	$^3F'$; $^1F'$	d^3F'; b^1F'
	b^2G	^3G; ^1G	—; d^1G
$(3d)^2\ 4s \cdot 6s$...	a^4F'	$^5F'$; $^3F'$	e^5F'; f^3F'

TABLE V—*Continued*

Configuration	Limit *Ti* II	Predicted Terms	Observed Terms
$(3d)^2\,4s\cdot 4d$..	a^4F'	$\begin{cases} ^5P'\ ^5D\ ^5F'\ ^5G\ ^5H' \\ ^3P'\ ^3D\ ^3F'\ ^3G\ ^3H' \end{cases}$	$\begin{cases} b^5P'\ b^5D\ d^5F'\ a^5G\ a^5H' \\ —\ —\ e^3F'\ c^3G \end{cases}$
	a^2F'	$\begin{cases} ^3P'\ ^3D\ ^3F'\ ^3G\ ^3H' \\ ^1P'\ ^1D\ ^1F'\ ^1G\ ^1H' \end{cases}$	$\begin{cases} —\ —\ g^3F'\ —\ b^3H' \\ —\ —\ c^1F'\ c^1G\ b^1H' \end{cases}$
$(3d)^2\,4s\cdot 5d$..	a^4F'	$^5P'\ ^5D\ ^5F'\ ^5G\ ^5H'$	$—\ e^5D\ h^5F'\ d^5G\ c^5H'$
$(3d)^3\,5s$.....	b^4F' b^2D a^2P'	$^5F';\ ^3F'$ $^3D;\ ^1D$ $^3P';\ ^1P'$	$c^5F';\ d^3F'$ $c^3D;\ —$ $—;\ b^1P'$
$(3d)^3\,6s$.....	b^4F'	$^5F';\ ^3F'$	$f^5F';\ —$
$(3d)^3\,4d$.....	b^4F'	$^5P'\ ^5D\ ^5F'\ ^5G\ ^5H'$	$c^5D\ —\ b^5G\ b^5H'$
$(3d)^2\,(4p)^2$...	a^3F' (*Ti* III)	$^5D\ ^5F'\ ^5G;\ ^3D\ ^3F'\ ^3G;$ $^1D\ ^1F'\ ^1G$	$d^5D\ g^5F'\ c^5G$

The quintet system.—As is usual in complex spectra, the system of highest multiplicity has the simplest structure. Only two low even terms are to be anticipated (arising from $(3d)^3 4s$), and these must evidently be a^5F' and a^5P'. Among the odd terms, at a middle level, four triads are to be anticipated, two of $D'FG'$ terms, combining strongly with a^5F', and the other two, of $S'PD'$ terms, combining strongly with a^5P', and exactly these terms are observed. For the triads of origin $(3d)^3 4p$ the electron jump for the low term is from s to p, and the multiplets of highest L value should be the strongest. This is the case for the higher of each pair of triads, as is illustrated in Table VI and also by the fact that the multiplet $a^5F'-b^5G'$ includes the *raies ultimes* of *Ti* I in the visible region. The other two triads must then arise from $(3d)^2 4s\cdot 4p$, and for these the multiplets of lowest L value should be the strongest. This is clearly so for $a^5P'-a^5S'$, which is recorded as equally strong photographically with $a^5P'-b^5D'$, though the former lies far in the infra-red. For the other triad, $a^5F'-a^5D'$ is very strong; the combination with a^5F is at the limit of observation and with a^5G' beyond it. This disposes of all the even terms except e^5D', which may be attributed to $(3d)^2 4s\cdot 5p$, with limit a^4F'. This conclusion is confirmed by series relations (sec. 8). The other terms of the triad, which should give weaker multiplets, have not been found.

The high even terms fall into two sharply separated groups, the larger composed of terms which combine with the lowest odd triad a^5D', a^5F, a^5G' and but weakly with anything else; the smaller, of terms which combine most strongly with the triad c^5D', b^5F, b^5G' and weakly with the lower triad. It is evident that these groups of terms must be derived from the same limits as these triads, namely, a^4F' and b^4F'. From the first limit we have the configurations $(3d)^2 4s \cdot ms$, giving an isolated $^5F'$ term, and $(3d)^2 4s \cdot md$, giving a pentad, $^5P'$, ^5D, $^5F'$, ^5G, $^5H'$. The term b^5F' meets the condition for the first, giving the strongest combination with a^5G', as it should.

The first pentad, of terms lying almost at the same level, is also immediately recognizable. The terms belonging to it alternate in level in the characteristic manner observed in other spectra. Four of the five terms belonging to it give multiplets consisting of decidedly fuzzy lines, denoted by "n" in Table VI.

The higher isolated term e^5F', which behaves like b^5F' but gives much fainter combinations, is apparently in series with it, and four out of the five members of the pentad, which is in series with the one already found, can easily be identified, giving, as they do, the most diffuse lines in the whole spectrum. In this pentad also the energy levels alternate, and the differences in level are about half those in the lower one.

Among the terms of the second group, which evidently arise from the configurations $(3d)^3 ms$ and $(3d)^3 md$, the term c^5F', although originally identified by means of its combinations with the lower triad, is shown to belong here by the strength of its combination with b^5G' in the deep red.

For the term next in series with it, f^5F', only the leading component has been identified, but the agreement with a series formula (sec. 8) makes its reality probable. Three of the five members of the pentad of origin $(3d)^3 4d$ have also been recognized.

This leaves three high even terms unclassified, e^5D, g^5F', c^5G. They lie nearly at the same level, give strong multiplets, and are evidently related to one another. All the configurations containing an excited s or d electron which are at all likely to give strong lines have already been accounted for, but the configuration $(3d)^2(4p)^2$ should produce terms of exactly the observed types. Similar terms

arising from the configurations involving two p electrons have been identified in *Ca* I[1] and *Sc* I.[2] It is of much interest to note that the relative intensities of the different multiplets resulting from the

TABLE VI

Ti I, Intensities of Strongest Lines, Quintet System*

		(3d)²4s·4p						(3d)³4p						(3d)²4s·5p
		a^5S'	a^5P	b^5D'	a^5D'	a^5F	a^5G'	b^5S'	b^5P	d^5D'	c^5D'	b^5F	b^5G'	e^5D'
(3d)³4s	a^5P'	(2)	(1)	(2)	*i*			15	30	30	(1)			
	a^5F'			3	(5)	(2h)	*i*			4	60	80	60	2
(3d)³5s	c^5F'	...	...	...	3	4n	1	...	...	...	*i*	*i*	(3)	
(3d)³6s	f^5F'	...	...	...	...	...	...	...	...	...	(1)	(2)		
(3d)³4d	c^5D	...	...	...	...	...	...	...	...	...	(1)	(2)		
	b^5G	...	...	...	...	...	...	...	...	...		(1)	(2)	
	b^5H'	...	...	...	...	...	...	...	...	...			5n	
(3d)²4s·5s .	b^5F'	...	...	...	12	15	18	...	...	...	*i*	*i*	*i*	
(3d)²4s·6s .	e^5F'	...	...	...	1	2	2							
(3d)²4s·4d.	b^5P'	...	...	...	10n									
	b^5D	...	...	...	8n	10n								
	d^5F'	...	...	...	7	5	2							
	a^5G	...	...	...		25n	15n							
	a^5H'	...	...	...		12n	30n							
(3d)²4s·5d .	d^5D	...	...	...	1n	2N								
	h^5F'	...	...	...	2n	1n	3n							
	d^5G	...	...	...		2N	6N							
	c^5H'	...	...	...		(1)	12N							
(3d)²(4p)² ..	e^5D	...	...	...	6	10								
	g^5F'	...	...	...	8n	1n	20n							
	c^5G	...	...	...		10	12							

* The table gives the intensity of the strongest unblended line in each multiplet; *i* denotes that the corresponding multiplet is in the infra red.

combinations of the terms arising from configurations such as (3d)²4s·4p and (3d)²4s·ms, (3d)²·4s·mp and (3d)²·4p·md, are remarkably similar to those of the individual lines resulting from

[1] Russell and Lang, *Mt. Wilson Contr.*, No. 337; *Astrophysical Journal*, **66**, 13, 1927.

[2] Russell and Meggers, *Scientific Papers of the Bureau of Standards*, **22**, 329 (No. 558), 1927.

the combination of a P term with S, P′, or D terms in a system of high multiplicity—the L values for the various terms of the triads or pentads taking the place of the j value for the components of the individual terms. The multiplet involving the greatest values of L is always the strongest, and even the finer details, such as the weakness of the middle line in a PP′ multiplet, and of the outer members of the middle set of three in a PD group, are faithfully reproduced. This relation, it is believed, was first noticed by the writer in *Sc* II. It is probably of general validity.

The quintet system is now satisfactorily interpreted. All the observed terms have been accounted for, and all the electronic configurations that might be expected to give lines of any strength have been identified, e.g., those terms, at least, which should theoretically be most prominent, except for $(3d)^4$. The reason why this has not been found will be discussed in section 9.

6. THEORETICAL INTERPRETATION OF THE OBSERVED TERMS: THE SINGLET SYSTEM

The singlet system is next in order of complexity. The low terms to be expected are S, D, G from the configuration $(3d)^2(4s)^2$, and P′, D, F′, G, H′, D from $(3d)^3 4s$. The terms of the former group may be expected to be the lower, since the second of a pair of equivalent s electrons is usually more tightly bound than the first. The first group may therefore be assigned as a^1S, a^1D, a^1G, leaving a^1P', b^1D, a^1F', b^1G, a^1H' for the other, and accounting for all the theoretical even terms except one ^1D term. This corresponds to a limiting term in *Ti* II which has not been observed, and which must give faint lines and be statistically improbable, so that the absence of the related term in *Ti* I is not surprising.

Confirming evidence in favor of this assignment is found in the relative levels of these terms and of the limits in *Ti* II. Subtracting the term values in *Ti* I from those in *Ti* II, we obtain a set of numbers which (since both sets of term values are measured upward from the lowest level) show how much greater or less is the energy involved in passing from a given term to its limit than from the lowest level in *Ti* I to that in *Ti* II. The resulting values for the first group are $a^1S+6172$, $a^1D+1489$, $a^1G+3139$, and for the second, $a^1P'-$

10087, $b^1D-7451$, $a^1F'-8927$, $b^1G-9169$, $a^1H'-8021$. The binding of the second 4s electron therefore involves more energy than that of the first by about 11,000 frequency units, or 1.35 volts.

Passing to the odd terms at middle levels, we must seek for triads related to the various limiting terms of *Ti* III. Some are easy to identify; for example, the three lowest odd terms, a^1D', a^1F, a^1G', which combine with a number of high even terms, clearly come from the lowest limit in *Ti* II, a^2F'.

The next lowest limit, a^2D, should give a triad combining with a^1D, to produce some of the strongest lines in the spectrum; a^1P, b^1D', b^1F (or perhaps c^1F) satisfy this condition. The middle term of the triad is more than 5000 frequency units below the other two, but similar differences are known in other spectra. From the limit b^2D should come a triad combining strongly with b^1D. The terms d^1F and e^1D' must belong to this (as the intensities given in Table VII show), and the most probable third member is c^1P (although d^1P might pass). To the limit a^2P' corresponds a triad combining with a^1P'. The unappropriated terms a^1S', d^1P, and d^1D' give the strongest combinations with this low term and may be placed here.

There should be a second $S'PD'$ triad, with limit b^2P', which, coming from $(3d)^2 4s \cdot 4p$, should combine more strongly with a^1S and a^1D than with a^1P'. The terms b^1P, c^1D' satisfy this test and may be placed here provisionally. The $^1S'$ term of this triad would be hard to identify and has not been found.

We may next seek the triads having the limits a^2H', a^2G, and b^2G. The first should be composed of G', H, and I' terms, combining strongly with a^1H'; a^1I' must certainly be assigned here, and b^1H very probably.

The terms derived from a^2G should combine strongly with b^1G, which has the same limit; and the intensities of the lines place a^1H and b^1G' unquestionably here. The last term to fill out the triad is b^1F, leaving c^1F for the triad with limit a^2D. The other $FG'H$ triad should combine strongly with a^1G, and, when permissible, with a^1D. Here we must now place c^1H; and c^1G' and e^1F appear to complete the group satisfactorily, leaving e^1G', which combines more strongly with a^1H' than with anything else, for the corresponding triad. For the remaining terms we might expect theoretically an isolated P

term with limit a^2S, and triads $D'FG'$ with limit b^2F', and $PD'F$ from c^2D. These limiting terms lie high, especially the last. The observed terms which are still unassigned are e^1P, f^1F, d^1G', and f^1G'. It is not practicable to allocate these with any confidence; f^1G' may belong to b^2F', and so may f^1F, although the combinations of both with a^1G are stronger than might be expected; e^1P may be associated with either a^1S' or c^1D'. The remaining term d^1G' depends only on three faint lines and may not even be real.

The high even terms remain to be discussed. Evidence will be given in section 8 that c^1D is in series with a^1D, and d^1G with a^1G. Most of the other terms combine with the lowest odd triad, and must, like this, have the limit a^2F'. The addition of a 4d electron to this should give a pentad, to which c^1F', c^1G, and b^1H' belong, as is indicated by their levels, the intensity of their combinations, and the term values given in section 8. The term b^1H' depends on a single observed line, $a^1G'-b^1H'$; but this should be the strongest combination between the triad and the pentad, and no other available line is in the proper region with the right intensity and Zeeman pattern.

Adding a 5s electron to a^2F' gives an isolated $^1F'$ term, which should be some 6000 units below the pentad; b^1F' is in just the right place for this. Finally, d^1D is at about the right level for a 4d derivative of a^2D, but its combinations do not fit this identification. It may arise from $(3d)^4$. The term b^1P' may arise from the addition of a 3d electron to a^2P. It combines most strongly with a^1S', as it should on this hypothesis, and is at the right level (sec. 6).

The arrangement of the terms which has finally been adopted is given in Table VII. It should be borne in mind that in some cases, especially in those marked with colons, the assignment of the terms to a given limit is less certain than in the case of the quintets; but the energy levels of the terms assigned to the same triad are usually near together, and the intensities appear to run satisfactorily, increasing, in general, with the L values in each principal triad of combinations, as they ought to do, since all the electron jumps are from s to p.

Some of the lines corresponding to double electron jumps are strong, but this is also the case in other spectra; for example, for the PP' group near λ 3000 in *Ca* I.

TABLE VII

Ti I, INTENSITIES OF SINGLET LINES

Configuration		$(3d)^2(4s)^2$			$(3d)^3 4s$					$(3d)^2 4s\cdot 5s$			$(3d)^2 4s\cdot 4d$			$(3d)^3 4d$	?
Limit	Term	a^1S	a^1D	a^1G	a^1P'	b^1D	a^1F'	b^1G	a^1H'	c^1D	b^1F'	d^1G	c^1F'	c^1G	b^1H'	b^1P'	d^1D
	$(3d)^2 4s\cdot 4p$																
a^2S	e^1P:	1	15		3	(2)											
b^2P'	—																
	b^1P	3	12		(1)											1	
	c^1D'		15		(0)											*m*	
a^2D	a^1P		20		(1)												(1)
	b^1D'		25		*i*					2						m	
	c^1F		20	5		1	*i*	(0)									
a^2F'	a^1D'		10		*i*					(3)	3		4n				1
	a^1F		12	*i*			*i*	*i*		2	4	2n	5n	5			1
	a^1G'			(3)			*i*	*i*	*i*		7	1	(1)	2	5		
b^2G	e^1F		40	10		1	(1)	*m*									
	c^1G'			20			*i*	6	8								
	c^1H			15					7								
	$(3d)^3 4p$																
a^2P'	a^1S'				2											(2)	
	d^1P	(1)	15		5	2										*m*	
	d^1D'		15		5											*i*	
b^2D	c^1P	(3)	15		(1)	4										(1)	
	e^1D'		6		4	7											
	d^1F		2	15		10	*i*	(1)									

b^2F'	—										
	f^1F:	(1)	20		(2)	4					
	f^1G':		30		(1)	8	10				
a^2G	b^1F	40n	20	(2)	*i*	6					
	b^1G'		25		*i*	18	3	(0)			
	a^1H		40			20	2				
a^2H'	e^1G'		2n		(0)	2n	5n				
	b^1H		6			8	8				
	a^1I'	....	....				12				
?	d^1G'		*m*			2	1				

i, in infra-red; *m*, masked by stronger line.

7. THEORETICAL INTERPRETATION OF THE OBSERVED TERMS: THE TRIPLET SYSTEM

The triplet system is much the most intricate, since triplet terms may arise from both doublet and quartet limits in *Ti* II. The lowest terms may be expected to come from the configuration $(3d)^2(4s)^2$, and to be of types $^3P'$, $^3F'$, the latter being the lower. These must obviously be the terms a^3P', a^3F'. From $(3d)^3 4s$ we should have, from the quartet terms in *Ti* II, $^3P'$ and $^3F'$, and, from the doublet terms, $^3P'$, ^3D, $^3F'$, ^3G, $^3H'$. All these are observed, except one $^3F'$ term. The terms a^3D, a^3G, and a^3H' fall naturally into the second group, while b^3F', which is at a lower level, evidently comes from the low limit, b^4F'. The limits a^2P' and a^4P' are very close together, and so are the terms b^3P' and c^3P', which are doubtless derived from them. Which belongs to which limit is hard to tell. As good a guide as any may be found in the differences of the energy levels in *Ti* I and the limits in *Ti* II. Taking differences of term values, as before, we find, for the transitions involving the completion of a pair of 4s electrons,

$$b^4P' - a^3P' = +1422 ; \qquad a^4F' - a^3F' = +7 .$$

For those where a single s electron is added and the multiplicity of the term increases, we have

$$b^2D - a^3D = -4782 , \quad a^2G - a^3G = -6102 , \quad a^2H' - a^3H' = -5418 .$$

For comparison we have

$$a^4P' - a^5P' = -4587 , \quad b^4F' - a^5F' = -5628 .$$

For the transitions in which one s electron is added but the multiplicity decreases, the difference is considerably greater (meaning that the energy of binding of the electron is less than when the multiplicity increases). We have $b^4F' - b^3F' = -10{,}561$, while the mean for five transitions from doublets to singlets (sec. 6) is -8919.

We should therefore expect differences of about -9200 for the term derived from a^4P' and -5300 for that coming from a^2P', putting them at levels near 18,700 and 15,300, respectively. The actual difference in level is much less, but it seems best to assign b^3P' to a^2P', giving a difference of -8170, and c^3P' to a^4P', with a differ-

ence of -9393. On the same basis the level of the $^3F'$ term derived from b^2F' should be about 26,000—which means that all its stronger combinations with the known odd terms should be in the infra-red, so that it is not surprising that it has not been detected.

The odd triplet terms should contain a great number of triads. Those which combine with the low F' terms should be especially conspicuous. We may expect to find two of origin $(3d)^2 4s \cdot 4p$ and limits a^4F' and a^2F', and two of origin $(3d)^3 4p$ and limits b^4F' and b^2F', the last high-lying and perhaps inconspicuous. The first pair of triads should combine very strongly with a^3F', and the second strongly with b^3F'. The strongest combinations of this term are with d^3D', c^3F, b^3G', and e^3F. The first three of these lie at nearly the same level, and evidently form the triad with limit b^4F'. They combine very strongly with a^3F' also. Another obvious triad is a^3D', a^3F, a^3G', which, like similar triads in the singlet and quintet systems, contains the lowest odd terms.

Another triad, which gives extremely strong combinations with a^3F' and relatively weak ones with b^3F', is formed by b^3D', b^3F, and c^3G'. This may be accepted as the second triad of origin $(d)^2 s \cdot p$. Which of these triads belongs to the limit a^4F', and which to a^2F', can hardly be determined from the data on the spectrum of *Ti* alone, extensive as they are; but a comparison of all the spectra from *Ca* to *Cu* shows conclusively[1] that the higher-lying triad, which gives the stronger combinations, belongs to the limit of higher multiplicity.

The limit a^2H' should give a $G'HI'$ triad, combining strongly with a^3H'. Much the strongest combinations from this level are with f^3G', c^3H, and a^3I', which are thus identified. There should be two $FG'H$ triads with limits a^2G and b^2G. Both should combine strongly with a^3G (the electron jumping from 4s to 4p in the first case, and 3d to 4p in the second); but the second should combine more strongly with a^3F' than the first. There is only one strong GG' multiplet involving e^3G', which evidently belongs in the first triad, and leaves available for the second only d^3G', which combines very strongly with a^3F', but much more weakly with a^3G than might be expected.

The strong GH multiplets involve a^3H and b^3H. The former

[1] *Mt. Wilson Contr.*, No. 341; *Astrophysical Journal*, **66**, 184, 1927.

term combines with a^3F', in spite of the unusual transition, and must be assigned to the second triad and b^3H to the first. The second triad is naturally completed by e^3F, which combines very strongly with a^3F'. For the other, f^3F or g^3F are at the right level; the latter has been adopted, and, like e^3G', it gives a much stronger combination with a^3F' than with b^3F'. The triads with large values of L are thus satisfactorily identified; those with small L's are harder to pick out.

There should be four S′PD′ triads, of origin $(3d)^2 4s \cdot 4p$ and limits b^4P', b^2P', and of origin $(3d)^3 4p$ with limits a^4P', a^2P'. The four known $^3S'$ terms show that all four triads exist, but to identify them completely is difficult. By analogy with the D′FG′ triads we might expect the one with limit b^2P' to be the lowest, and to give combinations of only moderate strength. The terms a^3S', a^3P, c^3D' fit these conditions. Except for the first, their combinations with a^3P' are faint; all three of them also combine with a^3F' and give groups with abnormal intensities.

The triad with limit b^4P' should give the strongest combinations with a^3P'. It seems clear that c^3P must belong to this triad. Unless the levels are very irregular, b^3S' must do so too. For the third term, f^3D', which combines strongly with both a^3P' and a^3F', appears to be the best choice.

The other two triads, with limits a^2P' and a^4P', should give distinctive combinations with b^3P' and c^3P', respectively. It is probable that f^3P and i^3D' belong to the first of these. The second should include h^3D' and either d^3P or e^3P. As the former gives a strong combination with a^3P', it is chosen in preference to the latter. It then appears reasonable, from consideration of energy levels, to put c^3S' in the latter triad and d^3S' in the former. It should be freely admitted, however, that the arrangement of these upper S′PD′ triads is subject to considerable uncertainty.

There should be two PD′F triads, with limits a^2D and b^2D, the latter giving strong combinations with a^3D. The unassigned terms e^3P and j^3D' fit in well here, as would either f^3F or h^3F. The former has been adopted because, like i^3D', it combines weakly with a^3F'. The other triad might be expected to be lower, and there are three unclassified terms, b^3P, e^3D', d^3F, which look well enough as regards

energy level. Their combinations, however, are weaker than might be expected, and not very satisfactory in intensity, so that this triad must remain doubtful.

Three more triads involving a 4p electron are to be anticipated, with limits c^2D, b^2F', and an unobserved ^2D term. The last is not likely to give identifiable terms; the second probably gives inconspicuous ones, but the first, coming from the configuration $3d(4s)^2 4p$, may combine with the low term of origin $(3d)^2(4s)^2$ and give strong multiplets. There are three terms at a very high level which give such strong combinations—g^3P, l^3D', and i^3F, and these have been grouped together. Among the remaining terms, those which give the strongest combinations are g^3D' and h^3F. These may be placed tentatively in the triad with limit b^2F'.

There remain the odd terms k^3D', m^3D', j^3F, g^3G', and d^3H, all of which give faint combinations. These probably arise from configurations containing a 5p electron, and it will be seen in section 8 that m^3D', j^3F, g^3G' are probably in series with the triad d^3D', c^3F, b^3G', and have the limit b^4F'. The other two terms have not been placed.

Fewer high even triplet terms have been found than might have been expected. There are several groups of three neighboring unclassified faint lines in the arc spectrum which point to the existence of other triplet terms, probably belonging to this group, but they cannot be definitely located. Of the known terms, c^3F' and f^3F' are in series with a^3F with limit a^4F', and a^3F' and d^3F' with limit a^2F' (sec. 8). The fragmentary terms c^3D and d^3P' appear to be the series members following a^3D and a^3P' (sec. 8). All the rest combine mainly, if not exclusively, with the low odd triad, a^3D', a^3F, a^3G'. This suggests that they belong to the pentads formed by adding a d electron to a^4F' or a^2F', and the term values indicate that e^3F' and c^3G probably belong to the first, and g^3F' and b^3H' to the second.

This leaves outstanding b^3G and b^3D. The former lies much too low to be derived from any of the terms of *Ti* II by adding either a 5s or a 4d electron, and can arise only from the configuration $(3d)^4$. This is confirmed by the comparison with *V* II given in section 9. It is highly probable that b^3D, which does not fit in well otherwise, comes from the same configuration.

The arrangement which has finally been adopted for the triplet terms is given in Table VIII, which is arranged like Tables VI and VII.

Practically all the observed terms of *Ti* I have now found their place in the scheme provided by Hund's theory. For a large majority of the terms the identification of the electronic configuration corresponding to each term is definite; for the remainder, although some ambiguity exists, it involves only the choice between interpretations, both of which are consistent with theory. The representation of the structure of this complex spectrum by Hund's theory leaves therefore nothing to be desired.

8. SERIES AND IONIZATION POTENTIAL

The foregoing analysis indicates that a considerable number of series can be identified in this spectrum. Only two of these, however, can be followed beyond the second member. These begin, as might have been anticipated, with the terms which give the strongest lines in the spectrum (a^3F' and a^5F') and, even so, the third members give such faint lines that only the leading component of the multiple terms could be found (by searching in the region predicted by a Rydberg formula). In both cases, however, the reality of these terms appears to be confirmed by the combinations in which they appear.

The term values of the leading components of a^3F', c^3F', f^3F' are exactly represented by the Ritz formula

$$x = A - \frac{R}{\{m+q+K(A-x)\}^2}\,,$$

if $A = 55{,}384$, $q = 0.5403$, $K = -2.36 \times 10^{-6}$; while for a^5F', c^5F', f^5F' the constants are

$$A = 56{,}500\,, \quad q = 0.5586\,, \quad K = -1.46 \times 10^{-6}\,.$$

The values of A give the heights of the limits of the two series above the lowest level, a^3F_2' in *Ti* I. These limits are the terms a^4F_4' and b^4F_5' of *Ti* II which lie at heights 393 and 1216 above the lowest level a^4F_2' of *Ti* II. The difference of the lowest levels in *Ti* I and *Ti* II is therefore 54,991 from the triplet, and 55,284 from the quintet series, corresponding to ionization potentials of 6.79 and 6.83 volts,

TABLE VIII

Ti I, Intensities of Strongest Lines, Triplet System

Configuration		$(3d)^2(4s)^2$		$(3d)^3 4s$						$(3d)^4$	
Limit		b^{4}P′	a^{4}F′	a^{4}P′	b^{4}F′	a^{2}P′	b^{2}D	a^{2}G	a^{2}H′		
		a^{3}P′	a^{3}F′	c^{3}P′	b^{3}F′	b^{3}P′	a^{3}D	a^{3}G	a^{3}H′	b^{3}D	b^{3}G
$(3d)^2 4s \cdot 4p$											
b^{4}P′	b^{3}S′	20				2					
	c^{3}P	30		(1)			(2)				
	f^{3}D′	15	40		8	1	8				
a^{4}F′	b^{3}D′	35	80	*i*	20	*i*	*i*				
	b^{3}F		100R		4		*i*	*i*			(1)
	c^{3}G′		80R		6			(1)	(3)		
b^{2}P′	a^{3}S′	20	(3)	*i*		*i*					
	a^{3}P	10	40	*i*	5	*i*	*i*				
	c^{3}D′	4	15	*i*	8	*i*	*i*				
a^{2}D	b^{3}P	2	tr			(2)	(1)				
	e^{3}D′	10	5	(1)	12	(2)	(1)				
	d^{3}F		20		8		3	6			
a^{2}F′	a^{3}D′	(3)	25	*i*	*i*	*i*	*i*			3	
	a^{3}F		40		*i*		*i*	*i*		5	(1)
	a^{3}G′		30		*i*			*i*	*i*		(2)
b^{2}G	e^{3}F		70R		40		4n	10			
	d^{3}G′		100R		25			4	(3)		
	a^{3}H		3					30	(1)		
$(3d)^3 4p$											
a^{4}P′	c^{3}S′	8				3					
	d^{3}P	12		6			8				
	h^{3}D′	6	20	12	3		(2)				
b^{4}F′	d^{3}D′	20	40r		25	(1)				(2)	
	c^{3}F		80r		25		*i*	(4)			
	b^{3}G′		100r		50			(4)	*i*		
a^{2}P′	d^{3}S′	6									
	f^{3}P	tr				8	8				
	i^{3}D′	12	(3)	2	8	6	3				
b^{2}D	e^{3}P	1		8			4				
	j^{3}D′	15	4		(5)		10				
	f^{3}F	1	5		3		12	15			
b^{2}F′	g^{3}D′	15	5		15	2	4				
	h^{3}F		10				10	4			
a^{2}G	g^{3}F	2	25		1		9	15			
	e^{3}G′		20		2			30	(1)		
	b^{3}H							20	9		

TABLE VIII—*Continued*

Configuration		$(3d)^2(4s)^2$		$(3d)^3 4s$						$(3d)^4$	
Limit		b^4P'	a^4F'	a^4P'	b^4F'	a^2P'	b^2D	a^2G	a^2H'		
		a^3P'	a^3F'	c^3P'	b^3F'	b^3P'	a^3D	a^3G	a^3H'	b^3D	b^3G
a^2H'.......	f^3G'		10		2				10n		
	c^3H							7	25		
	a^3I'								20		
$3d\,(4s)^2\,4p$											
c^2D.......	g^3P	30		1		3	1				
	l^3D'	6	12		1						
	i^3F		12		2			3			
$(3d)^3\cdot 5p$											
b^4F'.......	m^3D'	(4)	(7)		3						
	j^3F		(8)		2n						
	g^3G'		(3)					4			
?..........	k^3D'	5	(4)		2n						
	d^3H							6n			

		$(3d)^2 4s\cdot 5s$			$(3d)^2 4s\cdot 6s$	$(3d)^2 4s\cdot 4d$				$(3d)^3 5s$
		a^4F'	a^2F'	b^4P'	a^4F'	a^4F'		a^2F'		a^2D
		c^3F'	d^3F'	d^3P'	f^3F'	e^3F'	c^3G	g^3F'	b^3H'	c^3D
$3d\cdot 4s\cdot 4p$										
a^4F'.......	a^3D'	5		1	(1)	2				1
	a^3F	8			4n	3	5	2		2n
	a^3G'	20			3n	(0)	4	(2)	15	
a^2F'.......	b^3D'	(1n)	2							
	b^3F		(2)							
	c^3G'	*i*	*i*							
b^4P'.......	a^3S'			3						
$(3d)^3 4p$										
b^4F'.......	c^3F	(1)								
	b^3G'	*i*	(2h)							

respectively. The agreement is satisfactory, and we may adopt the mean, 6.81 volts, as the principal ionization potential of the neutral atom of titanium, or, which comes to the same thing, adopt $a^4F'_2 - a^3F'_2 = 55{,}138$.

It is now possible to locate accurately all the terms in *Ti* II with respect to the scale of levels employed for *Ti* I. For those terms

which have appeared above as limits of possible series in *Ti* I, we find by adding 55,138 to the levels referred to $a^4F'_2$ and taking always the component of greater inner-quantum number,

$a^4F'_5$.....	55,531	a^2S.....	76,476	b^2D_3....	67,896	a^2G_5....	64,256
$b^4F'_5$.....	56,354	$a^2P'_2$.....	65,114	c^2D_3....	80,331	b^2G_5....	70,396
$a^4P'_3$.....	64,656	$b^2P'_2$.....	71,763	$a^2F'_4$.....	60,036	$a^2H'_6$....	67,913
$b^4P'_3$....	65,163	a^2D_3....	63,882	$b^2F'_4$.....	76,030		

We may now compute the true term values and the Rydberg denominators for all the terms which have been classified in section 7. The results for those terms which form series are given in Table IX. The various series are arranged according to the types of electrons which shift, and, to save printing, only the Rydberg denominators are given. The term values can be found by subtracting the values given in Table I, taking always the component of highest inner-quantum number, from the appropriate limit, as listed above.

Seventeen series have been identified. The successive terms of each lie in the same horizontal row. When an s electron is involved the fractional part of the denominator is nearly the same for the terms of a given series. For a 5p electron it is greater by about 0.12 than for a 4p. For 4d and 5d it is nearly the same, but for 3d it is much less, showing that, as usual, the electron is much more firmly bound when it goes into a group of similar electrons than when it stands alone.

It should be noted that a^3F' is the leading term of two different series, one converging to a^4F' and the other to a^2F'. This arises from the fact that, by Pauli's restriction, the addition of a 4s electron to either of these terms of *Ti* II can give only this term in *Ti* I, while the addition of a 5s electron to the two gives four different terms, all of which have been identified.

The quantum defects are nearly the same for all the terms involving s electrons, considerably smaller for the p's, and smaller yet for the d's (excepting 3d). To complete the data regarding them, the denominators for the remaining terms are given in Table X, which is arranged in fashion very similar to Table IX. All the terms arising from the addition of 4s and 4p electrons are given; those from 3d electrons are given only when they do not appear in

Table IX. Certain cases, in which it is doubtful whether the term belongs in the assigned place, are marked with a question mark (?).

It appears from this table that the denominators are smaller and the quantum defects greater for those terms which originate from the configuration $(3d)^2 4s$ than for those which come from $(3d)^3$; i.e., an additional electron is more firmly bound to the first configuration

TABLE IX

RYDBERG DENOMINATORS FOR SERIES TERMS

SERIES LIMIT	ELECTRON					
	4s		5s		6s	
a^4F'	a^3F'	1.410	c^3F'	2.489	f^3F'	3.490
			b^5F'	2.456	e^5F'	3.420
b^4F'	a^5F'	1.489	c^5F'	2.544	f^5F'	3.576
b^4P'	a^3P'	1.392	d^3P'	2.408		
a^2D	a^1D	1.392	c^1D	2.384		
b^2D	a^3D	1.476	c^3D	2.450		
a^2F'	a^3F'	1.356	d^3F'	2.327		
			b^1F'	2.406		
b^2G	a^1G	1.372	d^1G	2.450		
	4p		5p			
a^4F'	a^5D'	1.726	e^5D'	2.856		
b^4F'	d^3D'	2.040	m^3D'	3.136		
	c^3F	1.934	j^3F	3.114		
	b^3G'	1.958	g^3G'	3.026		
	3d		4d		5d	
a^4F'	....		b^5D	2.866	d^5D	3.860
	a^5F'	1.516	d^5F'	2.998	h^5F'	4.027
			a^5G	2.849	d^5G	3.875
			a^5H'	2.869	c^5H'	3.883
	b^3F'	1.583	e^3F'	2.858		

than the second. The binding is also closer when the multiplicity increases on adding the new electron than when it decreases. The mean values of the quantum defect, omitting the doubtful cases, are as shown in Table XI, the number of cases being indicated by figures in parentheses. These values may be taken as a measure of the failure of complete screening of the attraction of the nucleus by the outer electrons. The screening is of course greatest for the d, and least for the s orbits; conversely, an electron already in the

TABLE X

Rydberg Denominators for Other Terms

Series Limit	Electron							
	4s		4p		4p		4d	
a^4F'	a^3F'	1.410	a^5D'	1.726	b^3D'	1.916	b^5P'	2.941
			a^5F	1.692	b^3F	1.908	c^3G	2.794
			a^5G'	1.675	c^3G'	2.074		
b^4F'	a^5F'	1.489	c^5D'	2.042	d^3D'	2.040	c^5D	3.027
	b^3F'	1.568	b^5F	1.989	c^3F	1.934	b^5G	3.240
			b^5G'	1.930	b^3G'	1.958	b^5H'	2.996
a^4P'	a^5P'	1.474	b^5S'	2.006	c^3S'	2.146		
	c^3P'	1.548	b^5P	1.971	d^3P	2.003		
			d^5D'	1.948	h^3D'	2.097		
b^4P'	a^3P'	1.392	a^5S'	1.655	b^3S'	1.921		
			a^5P	1.716	c^3P	1.850		
			b^5D'	1.672	f^3D'	2.015		
a^2S	a^1S	1.337	....		e^1P	1.808?		
a^2P'	b^3P'	1.528	d^3S'	2.327	a^1S'	2.018	b^1P'	3.095
	a^1P'	1.560	f^3P	2.175	d^1P	2.060		
			i^3D'	2.124	d^1D'	2.264		
b^2P'	a^3P'	1.318	a^3S'	1.530				
			a^3P	1.540	b^1P	1.726		
			c^3D'	1.574	c^1D'	1.728		
a^2D	a^1D	1.392	b^3P	1.849	a^1P	1.905	d^1D	2.824?
			e^3D'	1.832	b^1D'	1.746		
			d^3F	1.906	c^1F	2.043		
b^2D	a^3D	1.476	e^3P	2.000	c^1P	1.951		
	b^1D	1.517	j^3D'	2.070	e^1D'	2.134		
			f^3F	1.911	d^1F	1.994		
c^2D	....		g^3P	1.766				
			l^3D'	1.743				
			i^3F	1.731				
a^2F'	a^3F'	1.356	a^3D'	1.658	a^1D'	1.700	g^3F'	2.923
			a^3F	1.646	a^1F	1.707	b^3H'	2.791
			a^3G'	1.692	a^1G'	1.772	c^1F'	2.862
							c^1G	2.802
							b^1H'	2.745
b^2F'	b^1F'	1.541	g^3D'	1.716?	f^1F	1.991?		
			h^3F	1.785?	f^1G'	1.921?		
a^2G	a^3G	1.496	g^3F	2.070	b^1F	1.861		
	b^1G	1.545	e^3G'	2.032	b^1G'	1.970		
			b^3H	1.959	a^1H	1.927		
b^2G	a^1G	1.372	e^3F	1.741	e^1F	1.951		
			d^3G'	1.661	c^1G'	1.868		
			a^3H	1.690	c^1H	2.045		
a^2H'	a^3H'	1.485	f^3G'	2.032	e^1G'	2.127		
	a^1H'	1.526	c^3H	1.954	b^1H	2.020		
			a^3I'	1.940	a^1I'	1.994		

atom in a 3d orbit produces more screening upon an added electron of whatever sort than does one in a 4s orbit. For the terms which have been tentatively assigned to the addition of a 4p electron to the term c^2D (arising from $3d(4s)^2$), the mean quantum defect is 2.255, indicating a still smaller screening and confirming this interpretation. Since the assignment of the various terms to their limits was made primarily on the basis of the intensities of their combinations, the systematic character of the results just obtained may be taken as further and convincing evidence of the general correctness of the interpretation.

TABLE XI

QUANTUM DEFECTS

Electron Added	Configuration (*Ti* II)			
	$(3d)^2 4s$		$(3d)^3$	
4s	2.632	(7)	2.481	(13)
5s	2.583	(7)	2.503	(2)
6s	2.545	(2)	2.424	(1)
4p	2.219	(35)	1.975	(36)
5p	2.144	(1)	1.908	(3)
3d	1.450	(2)	....	....
4d	1.145	(13)	0.910	(4)
5d	1.089	(4)	....	....

Odd terms, arising from configurations involving a 4f electron, might theoretically be expected; but for such terms the quantum defect should be small. The term values should therefore be of the order of 7000, referred to their own limits, and the lowest of them should be at least 48,000 above the base-level used in Table I. None of the odd terms which have been observed lie so high. The terms with limit a^4F' should give combinations with a^3P, lying near λ 2050, where the arc spectrum is unknown; those with limit b^4F' should give combinations with a^5F' lying near λ 2350 and with d^3F' near λ 2650, but nothing of the sort can be recognized there.

9. COMPARISON OF *Ti* I AND *V* II

The analysis of the principal terms of the spark spectrum of vanadium by Meggers[1] invites comparison with the titanium arc.

[1] *Zeitschrift für Physik*, **33**, 509, 1925; **39**, 114, 1926.

The most satisfactory method is the application of Moseley's law, as discussed in Part I of this paper.[1] From the run of the values for spectra of elements earlier in the first long period there given it appears that in this case the differences $\Delta\sqrt{\nu/R}$, for terms derived from their limits by the addition of a 3d, 4s or 4p electron, should be very close to 0.51, 0.34, and 0.33, respectively.

TABLE XII

TERMS OF *V* II

Term	Level	Term	Level	Term	Level
a^5D_4	339	$a^3F'_4$	9097	a^3G_5	14,655
$a^5F'_5$	3163	$a^3P'_2$	11,908	b^3G_5	16,532
$a^5P'_3$	13,741	$b^3F'_4$	13,608	$a^3H'_6$	20,363
$a^5G'_6$	35,483	$a^3D'_3$	36,919	a^3P_2	46,123
a^5F_5	37,352	$b^3D'_3$	37,205	a^3H_6	47,607
$a^5D'_4$	37,531	$a^3G'_5$	39,612	$a^3I'_7$	52,252
$b^5D'_4$	47,420	a^3F_4	40,430	$b^3I'_7$	53,319
a^5P_3	47,051			$a^3S'_1$	58,461
$a^5S'_2$	49,731				

No series are known in *V* II, and it is necessary, in order to apply Moseley's law, to identify the electronic configurations corresponding to some at least of the terms, assume that the law holds for these, derive the corresponding ionization potential, and then test our assumptions by the values of $\Delta\sqrt{\nu/R}$ for other terms.

The known terms of *V* II, with their levels referred to the lowest term $^5D_0$, are listed in Table XII. Only the leading components are given, and Meggers' notation of primed and unprimed terms is reversed to correspond with Heisenberg's general rule. Designating letters—always an "a"—have been added in some cases when Meggers has not used them.

From analogy with other spectra it is practically certain that the lowest terms of *V* III will be a $^4F'$ and $^4P'$ derived from the configuration $(3d)^3$, the former being the lower. The $^4F'$ term identified by Gibbs and White[2] arises from $(3d)^2 4s$ and probably lies much higher.

[1] *Mt. Wilson Contr.*, No. 344; *Astrophysical Journal*, **66**, 283, 1927.

[2] *Physical Review*, Ser. 2, **29**, 658, 1927.

In *V* II the low terms should come from $(3d)^4$ and $(3d)^3 4s$, the former giving ^5D, $^3F'$, $^3P'$, $^3P'$, ^3D, $^3F'$, ^3G, $^3H'$, and the latter $^5F'$, $^5P'$, $^3P'$, ^3D, $^3F'$, ^3G, $^3H'$, ^3D, neglecting singlet terms.

The three low quintet terms are exactly what is to be expected,[1] and the higher odd quintet terms evidently form the two triads of origin $(3d)^3 4p$ and limits $^4F'$ and $^4P'$. Among the low triplet terms all that can be said with certainty is that one ^3G term must come from $(3d)^4$ and the other from $(3d)^3 4s$. The intensities of the combinations, as Meggers points out, show that a^3F' and a^3G are related, and also b^3F' and b^3G, the former combining strongly with a^3D', b^3D', a^3F, and a^3G', as far as the ordinary rules permit, and the latter only with a^3F. It may be noted in passing that there is place for only one odd $^3I'$ term in Hund's scheme, namely, that derived from $(3d)^3 4p$. The term called by Meggers a^3I' appears actually to combine with b^3G', giving lines observed in the spark by Exner and Haschek; so it is probably a ^3H term, which removes the discrepancy.

The terms a^5F' in *Ti* I and a^5F' in *V* II are evidently homologous, and b^3F' and a^3F' look promising. For the first the value of $\sqrt{\nu/R}$ is 0.671 in *Ti* I. Adding 0.34, we have 1.01 for the second, indicating that the limit $^4F'_5$ is higher than the term $^5F'_5$ in *V* II by 111,800 units, or above the low level of *V* II by 115,000 (to the nearest hundred). From a consideration of certain similar cases, the value 114,600 was adopted for this quantity, corresponding to an ionization potential of 14.1 volts. The values of $\sqrt{\nu/R}$ can then be computed for all the terms of *V* II which may be legitimately associated with the lowest limit a^4F' in *V* III. Strictly speaking, these are rather few, but such terms as $^5P'$ and the low $^3D'FG'$ triad, which arise from the same electronic configuration, are likely to give nearly the same $\Delta\sqrt{\nu/R}$ when referred to a^4F' as when referred to their proper limits (a^4P' or a^2F'), since the differences in level of the limits in *Ti* II and *V* III increase almost *pari passu* with the term values.

We thus obtain the comparison given in Table XIII, which is arranged similarly to Table VI in Part I of this paper. The designations in the second column give first the term in *Ti* I, then the cor-

[1] Hund, *op. cit.*, p. 159.

responding one in *V* II. The differences in $\sqrt{\nu/R}$ run with remarkable smoothness, averaging 0.341 for the 4s electron and 0.339 for 4p. For the first two entries in the table the agreement with the expected values is forced, but free for all the others. A change of the assumed ionization potential by ± 0.5 volts would alter the mean values by approximately ± 0.019 for 4s and ± 0.022 for 4p. They

TABLE XIII

COMPARISON OF *Ti* I AND *V* II

ELECTRON REMOVED	TERMS	LIMIT	$\sqrt{\nu/R}$			SEPARATIONS		
			Ti I	*V* II	DIFF.	*Ti* I	*V* II	Ratio
4s....	(3d)^3 4s							
	a, a^{5}F′	^{4}F′	0.671	1.008	0.337	286	558	0.51
	a, a^{5}P′	^{4}F′	.620	0.959	.339	124	230	.54
	b, a^{3}F′	^{4}F′	.638	.980	.342	245	458	.54
	a, a^{3}G	^{4}F′	.612	.954	.342	112	194	0.58
	a, a^{3}H′	^{4}F′	.590	.933	.343	155	121	(1.28)
4p....	(3d)^3 4p							
	c, a^{5}D′	^{4}F′	.489	.839	.350	231	429	0.54
	b, a^{5}F	^{4}F′	.501	.840	.339	108	(202)	.53*
	b, a^{5}G′	^{4}F′	.518	.850	.332	426	891	.48
	b, a^{5}S′	^{4}F′	.417	.769	.352			
	b, a^{5}P	^{4}F′	.426	.785	.359	116	298	.39
	d, b^{5}D′	^{4}F′	.434	.784	.350	254	834	.30
	d {a^{3}D′	^{4}F′	.522	.841	.319	251	430	0.58
	{b	^{4}F′	.522	.840	.318	251	247	(1.02)
	c, a^{3}F	^{4}F′	.496	.823	.327	222	428	0.52
	b, a^{3}G′	^{4}F′	.503	0.827	.324	251	379	.66
3d....	(3d)^4							
	—, a^{5}D	^{4}F′	....	1.021	....	....	339	
	—, b^{3}F′	^{4}F′	....	0.960	....	....	118	
	b, b^{3}G	^{4}F′	0.429	.946	0.517	135	191	0.71
	—, a^{3}P′	^{4}F′	....	0.968	....	....	613	

* Separation of the first two components; the rest have not been identified in *V* II.

accord so well with the values to be expected from comparison with other spectra as to indicate that the assumed value is probably correct within ± 0.5 volts.

The ratios of the extreme separations of the multiple terms are given in the last column. Most of these are near to the value 0.5, which might have been anticipated (cf. Part I, sec. 10). The principal exceptions involve the terms a^{3}H′ in *Ti* I and b^{5}D′ in *V* II, both of which have very abnormal intervals.

There appear, therefore, to be strong reasons for assigning the designated terms in *V* II to the configurations $(3d)^3 4s$ and $(3d)^3 4p$. An exception should be noted in the case of a^3F, for which the intensities of the combinations indicate a different origin, which must be $(3d)^2 4s \cdot 4p$. It looks also as if b^3D' might belong to this configuration, while a^3D' fits in well with the other. As for the configuration $(3d)^4$, there can be no hesitation in assigning to it the terms here listed for *V* II. (The ^3P term is much too low to be the one homologous with b^3P' in *Ti* I, for which $\sqrt{\nu/R}$ is 0.590). The only term identified during the analysis of *Ti* I as certainly due to this configuration is b^3G, which gives the expected value of $\Delta\sqrt{\nu/R}$. If this difference is the same for the terms in *Ti* I homologous with the other known terms of *V* II, the ^5D term (referred to the lowest level in *Ti* I) should lie at the level 28,500, and all its combinations of any strength must be in the infra-red, which explains why it has not been detected. The $^3P'$ and $^3F'$ terms should lie at about 34,100 and 34,800. They would combine strongly only with terms of origin $(3d)^3 4p$, and these again give infra-red lines. It is not surprising that their faint combinations with the low odd terms of origin $(3d)^2 4s \cdot 4p$ have been missed.

10. SUMMARY

It may be appropriate in conclusion to summarize the results obtained in the discussion of the spectra of titanium in the various degrees of ionization, as is done in Table XIV. The number of energy levels, or separate components of the terms, represents the number of distinct states in which the atom in this degree of ionization is known to exist. The whole number of such states, for all four degrees of ionization together, is 545; of multiplets which have been identified, 629; and of lines classified, 2045.

As the number of valency electrons increases, the complexity of the spectrum becomes great. The number of terms and multiplets is very large, and that of the various identifiable electron configurations in the atom increases. It is worthy of remark, however, that a greater variety of electron orbits has been identified in the simple "stripped" atom *Ti* IV than in any other state.

The final outcome of this long investigation may be summarized in a sentence. The present theories of atomic and spectral structure suffice to give a most satisfactory account, in full and complete detail, of all the features of the very complex spectrum of titanium.

TABLE XIV

SUMMARY

Systems Present	*Ti* I; Quintets Triplets, Singlets	*Ti* II; Quartets Doublets	*Ti* III; Triplets Singlets	*Ti* IV; Doublets
Types of terms	S to H S′ to I′	S to H S′ to H′	S to G P′ to D′	S to H
Number of terms	142	49	19	12
Number of energy levels	364	123	40	18
Number of multiplets	422	164	28	15
Number of lines classified	1394	529	90	31
Number of series found	17	4	2	4
Ionization potential, volts	6.81	13.58	27.6	43.08
Electron configurations:				
Low even	$(3d)^2 4s^{2*}$	$(3d)(4s)^2$		
	$(3d)^3 4s$	$(3d)^2 4s^*$	$3d\,4s$	$4s$
	$(3d)^4$	$(3d)^3$	$(3d)^{2*}$	$3d^*$
Odd	$(3d)^2 4s \cdot 4p^*$	$3d \cdot 4s \cdot 4p$	$4s \cdot 4p$	$4p$
	$(3d)^3 4s \cdot 5p$	$(3d)^2 \cdot 4p^*$	$3d \cdot 4p^*$	$5p$
	$(3d)^3 4p$	....	....	$4f$
	$(3d) \cdot {}^3 5p$			
High even	$(3d)^2 4s \cdot 5s^*$	$(3d)^2 \cdot 5s^*$	$3d \cdot 4d$	$5s$:
	$(3d)^2 4s \cdot 6s$	$(3d)^2 \cdot 4d$	....	$6s$:
	$(3d)^2 4s \cdot 4d$	....	....	$4d$
	$(3d)^2 4s \cdot 5d$	....	....	$5d$
	$(3d)^2 (4p)^2$	....	....	$5g$
	$(3d)^3 5s$	....	....	$6h$
	$(3d)^3 6s$	....	....	....
	$(3d)^3 4d$	....	....	$7h$

* This configuration gives the lowest energy level among the group in which it falls.

All the lines of any prominence have been classified, and it is reasonably certain that no important low terms have escaped notice. There are many faint unidentified lines, however, and a few stronger ones in the arc spectrum in the far ultra-violet, which show that there is still more work to be done, presumably in the study of the higher energy levels. The data already obtained, however, should suffice for astrophysical investigation, and they afford extensive material

for both observational and theoretical studies of line intensities, term separations, and relative levels of terms arising from the same configuration.

To the writer's many colleagues, who have generously supplied him with material and aided in many other ways, he desires to record once more his gratitude; for himself the interest of the work itself has been an abundant reward.

Carnegie Institution of Washington
Mount Wilson Observatory
May 23, 1927

ON THE SPECTRA OF COMETS

By N. T. BOBROVNIKOFF

ABSTRACT

The spectra of twenty-two comets which were obtained during the period from 1908 to 1927 at the Yerkes Observatory, with the Zeiss 6-inch ultra-violet camera and objective prisms, have now been studied photometrically. A self-registering microphotometer with a thermopile was used for this purpose. The spectrum of comet 1927 *d* (Stearns) was observed visually at a heliocentric distance 3.7 astronomical units.

Evidence for existence in the comets of *two distinct types of continuous spectrum* is obtained. One spectrum has its maximum of intensity near λ 4700 and has been called the "solar-type spectrum." The other, with its maximum at about λ 4000, has been called the "violet-type spectrum." A correlation between the heliocentric distance of the comet and the type of the continuous spectrum is established. At $r<0.7$ astronomical units the solar spectrum is usually predominant; at $r>0.7$, the violet. No definite correlation between the type of the spectrum and the phase-angle of the comet is found.

Sudden changes in the spectrum of the comets are studied, especially in comet Delavan (1914 V). Similar changes in the spectrum of Halley's comet have been described in a previous publication. The spectrum of different parts of the comet is isolated and compared with direct photographs. Two cases of contradiction to Bredichin's theory of cometary forms are found—comets Delavan and Gale (1912 II) had the same spectrum for both tails.

Reasons are given in favor of the *fluorescent origin* of the cometary spectrum.

The photographs of the spectra of twenty-two comets were obtained at the Yerkes Observatory during the period from 1908 to 1927. The instrument used was the Zeiss ultra-violet camera (aperture 14.5 cm, focal length 81.4 cm) with the objective prisms of 15°, 30°, and a combination of both. The scale between $H\beta$ (λ 4861) and $H\theta$ (λ 3798) is 3.1, 6.3, and 9.4 mm, respectively. Before 1925 the spectra were obtained chiefly by J. A. Parkhurst; after that time, by the present writer. The direct photographs were taken by E. E. Barnard with the Bruce telescope. The spectra of five of the comets have not been discussed elsewhere. They are: 1910 V (Faye periodic), 1913 V (Giacobini periodic), 1913 VI (Westphal periodic), 1925 *j* (Van Biesbroeck), 1925 *k* (Peltier). The spectrum of comet 1927 *d* (Stearns) was observed visually. Universal time is used throughout this paper.

The cometary spectra were measured in the usual way for the determination of the wave-lengths. The wire of the measuring machine was set on the brightest part of the condensation. The wave-length of the cyanogen fourth group was adopted as λ 3883,

and the rest of the wave-lengths were derived by means of a curve based on the lines of the Balmer series in the spectrum of the comparison star. On the scale employed only approximate measurements could be made. The prominent cometary group at λ 4000–λ 4100 was ascribed to $C+H$ (Raffety bands). The following notation was adopted: Swan Yellow Group *C* II (λ 5635); Swan Green Group *C* III (λ 5165); Swan Blue Group *C* IV (λ 4737); Swan Violet Group *C* V (λ 4382); Cyanogen Second Group *CN* II (λ 4606); Cyanogen Third Group *CN* III (λ 4216); Cyanogen Fourth Group *CN* IV (λ 3883); Cyanogen Fifth Group *CN* V (λ 3586).

The spectral plates were studied by means of a self-registering microphotometer with a Coblenz thermopile by the method described in a previous publication on the spectrum of Halley's comet.[1] In that paper two kinds of continuous spectrum of Halley's comet were described. One was called conventionally the "solar-type spectrum" since it has the same maximum of intensity (at about λ 4700) and the same general run as the spectrum of Capella taken with the same instrument and the same dispersion. Its variation in intensity with the heliocentric distance of the comet considered at three different places of the spectrum followed approximately the theoretical curve based on the assumption of the reflected solar light. The other kind of the continuous spectrum was called the "violet-type spectrum." It has the maximum of intensity at λ 4000. The close approach of the comet to the sun was associated with the development of the solar-type spectrum. The comets studied in the present paper show the same features.

SPECTRA OF TWENTY-THREE COMETS

1. *Comet 1908 III* (*Morehouse*).—The spectral plates of the comet used in this work have been previously measured and discussed by E. B. Frost and J. A. Parkhurst.[2] This comet has also been studied extensively by different writers.

The microphotometric records reveal a comparatively weak continuous spectrum of the violet type with a strong maximum of intensity at λ 4000. On this continuous spectrum were superposed the

[1] *Astrophysical Journal*, **66**, 145, 1927.

[2] *Ibid.*, **29**, 55, 1909.

caudal emissions of CO^+. No change in the distribution of energy in the spectrum was noticed during the period of observation (October 28–December 2, 1908) although r changed from 1.51 to 1.02 astronomical units. The list of the plates is given in Table I. The elimination of the continuous spectrum presented considerable difficulty, and no attempt was made in this direction. The head *CN* IV was influenced mostly by the changes in the continuous spectrum,

TABLE I

No. OP	Date	Mid-Exposure	Exposure Time	Photographic Density of *CN* IV	Plate
212	Oct. 29	0^h45^m	60^m	0.53	Seed 27
213	Oct. 29	1 55	60	.89	Sigma
214	Oct. 29	2 07	25	.69	Seed 27
215	Oct. 30	0 31	28	0.83	Seed 27
216	Oct. 30	1 27	35	1.43	Sigma
217	Oct. 30	3 04	34	0.99	Sigma
219	Nov. 1	0 48	21	1.90	Sigma
221A	Nov. 1	2 25	5	1.09	Seed 27
221B	Nov. 1	2 34	10	1 10	Seed 27
221C	Nov. 1	2 45	15	1.17	Seed 27
222	Nov. 1	3 26	61	1.55	Sigma
223	Nov. 6	0 14	15	0.95	Sigma
224	Nov. 6	0 29	10	1.07	Sigma
226	Nov. 6	1 07	7	0.97	Sigma
227	Nov. 12	0 40	35	2.00	Sigma
229	Nov. 20	0 10	60	1.45	Sigma
230A	Nov. 20	0 45	7	1.64	Sigma
230B	Nov. 20	0 58	16	1.62	Sigma
232	Nov. 21	23 51	30	0.86	Seed 27
235	Nov. 28	23 38	22	.78	Seed 27
238	Dec. 1	23 40	20	.95	Seed 27
239	Dec. 2	23 34	20	0.95	Seed 27

so that we may take its brightness as the maximum of the continuous spectrum. Photographic density of this head is given in the fifth column of the table. It was reduced to the exposure time of thirty-five minutes for all plates. The values of density for the Sigma plates came out considerably larger than for the Seed 27 plates. There are many changes in the density of the image which cannot be explained by the errors of measurement. Probably these changes of irregular character are real. The values of density were not corrected for the atmospheric absorption because of the lack of data, but these corrections cannot be large, judging by the description of

the atmospheric conditions. The functions $f=r^{-2}\,\Delta^{-2}$ and $r^{-4}\,\Delta^{-2}$ both give for this period almost a straight line.

A sharp increase in brightness of the *CN* IV band on November 12 is noticeable. Probably it means a real change in the continuous spectrum since the head *CN* IV does not differ in general aspect from other plates.

Figure 1, *a* gives the intensity curves of the spectrum of the comet on October 30, 1908 (Plate OP217). The spectrum was placed on the slit of the microphotometer in this way: (1) the nucleus; (2) 0.5 mm across the tail parallel to the nuclear line, and so on as is indicated in Table II. The distance from the nucleus is given in

TABLE II

Curve	Millimeters	Minutes of Arc	1000 Km.
1	0	0	0
2	0.5	2.1	72
3	1.5	6.3	220
4	2.5	10.5	369
5	3.5	14.7	507
6	5.0	21.0	861
7	7.5	31.5	1100
8	11.0	46.1	1579

millimeters, minutes of arc, and thousands of kilometers, assuming that the axis of the tail coincided with the prolonged radius vector, which in this case cannot be far from the truth.

The places of the cross-sections were carefully selected to avoid any interference of the stellar spectra of the background. Slender sharp monochromatic images of the tail made possible the study of the intensity curves far from the nucleus.

It is evident from the curves that the *CN* IV band, one of the strongest in the nucleus, disappears almost totally at a distance of 70,000 km from the nucleus. On the other hand, the CO^+ emissions are very strong even at a distance of 1,000,000 km. The Swan band *C* IV behaves in the same way as *CN* IV. The spectrum of the tail in the distribution of intensity is almost identical with that of the nucleus not far into the tail. It is of gaseous type with a characteristic continuous spectrum, the maximum of intensity of which is at

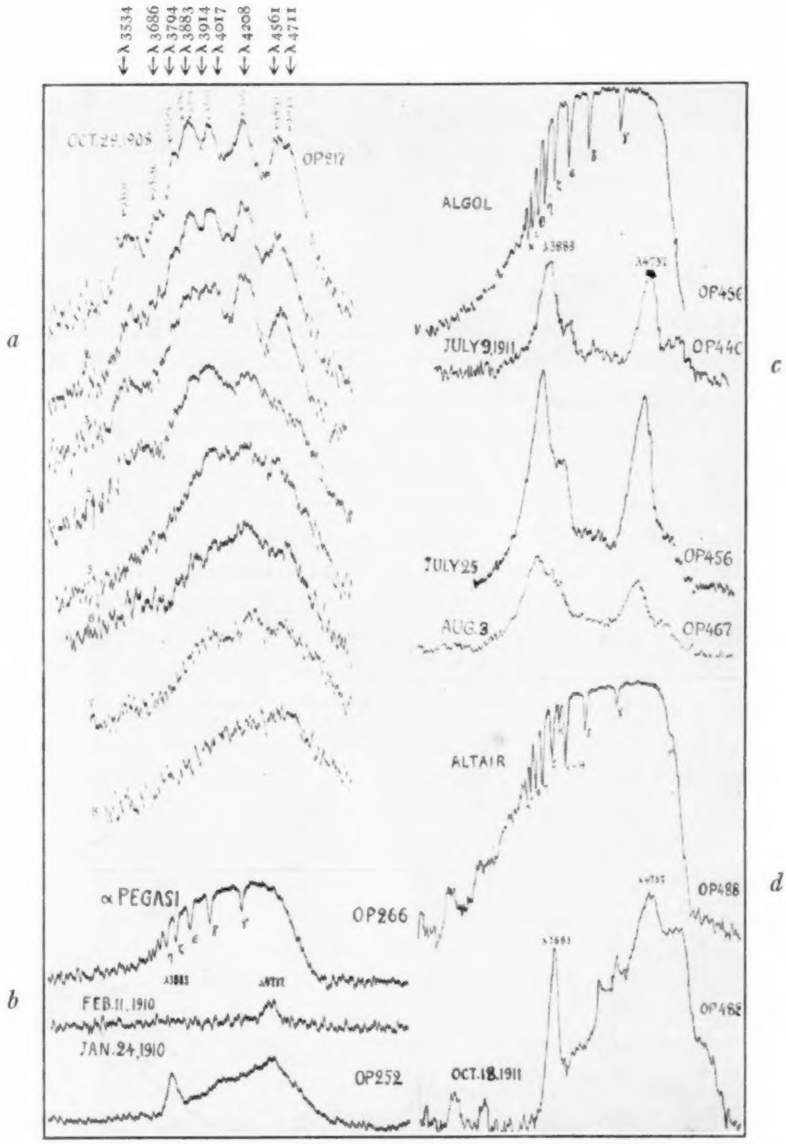


FIG. 1.—*a*, Comet 1908 III (Morehouse)
b, Comet 1910 I (Great)
c, Comet 1911 II (Kiess)
d, Comet 1911 IV (Beliavsky)

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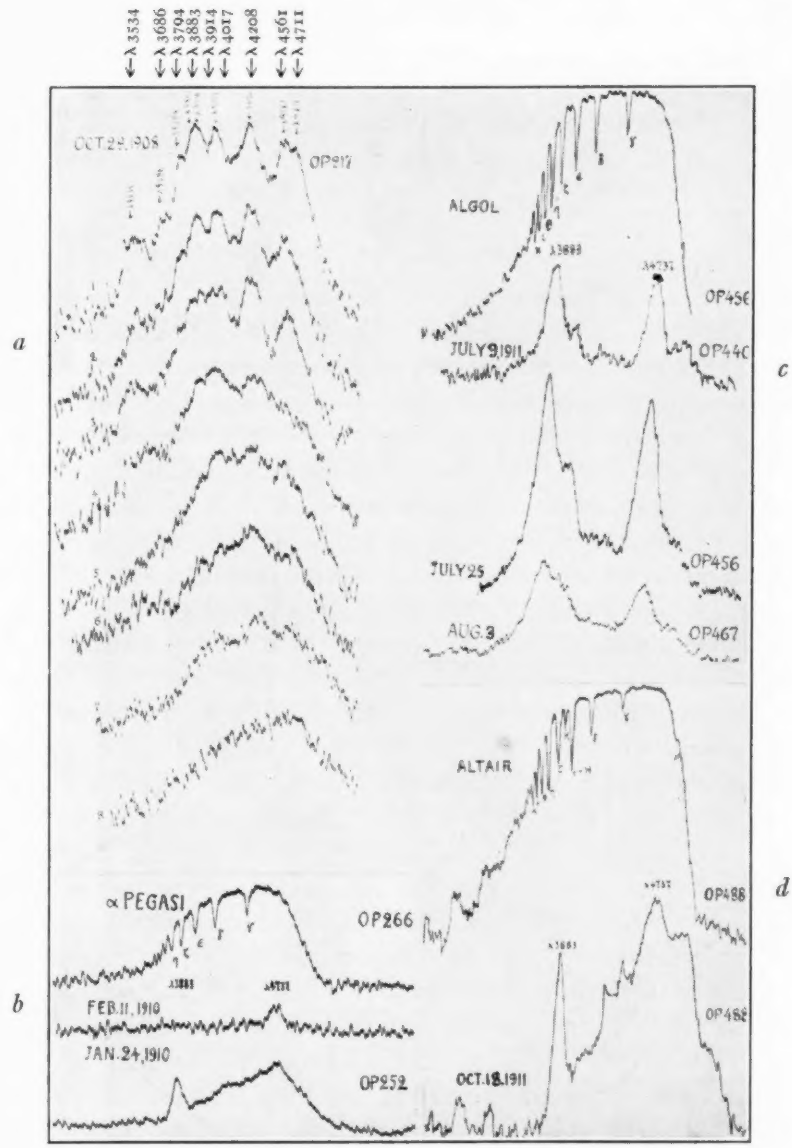

FIG. 1.—*a*, Comet 1908 III (Morehouse)
b, Comet 1910 I (Great)
c, Comet 1911 II (Kiess)
d, Comet 1911 IV (Beliavsky)

λ 4000. But a gradual shift of the maximum of intensity of the continuous spectrum toward the red is clearly seen. Curve 6 gives the maximum already at about λ 4200. Farther in the tail we have the continuous spectrum of the solar type.

This result may be interpreted as follows: sunlight, reflected by the particles much larger than the gaseous molecules, was always present in the tail, but its amount was insignificant in comparison with the radiations of CO^+ and N_2^+ molecules and the continuous spectrum of the violet type. The cometary gases were losing their radiative property with the recession from the nucleus and at a distance of 700,000–800,000 km became so inactive that the solar reflected light was no longer overpowered by them. Farther on, only reflected light was given off by the particles. The approximate ratio of intensities of the continuous spectrum at its maximum in the nucleus and of the continuous spectrum of curve 8, which is solar, is 7:1. The small dispersion and scale of the plates do not allow more precise measurements and a quantitative treatment of the subject.

It is impossible to explain this result by the superposition of the spectral images of the tail. There was on that plate a bifurcation of the tail, but one branch of it was very weak in comparison with the other. Furthermore, the effect of bifurcation would work in the opposite direction in the shift of intensity and would give a sharp change on curve 3, whereas the shift developed gradually. Again, the group of emissions at λ 3500 is so characteristic of each curve that it gives an unmistakable sign by which the curves should be arranged below one another. The red end of the curves may also serve for the same purpose. Plate OP229, November 29, gives a similar set of curves, and almost every plate upon visual examination shows the shift of intensity.

The center of the head C IV on all plates is not on the line joining other heads. It is shifted in the direction opposite to the tail. For Plate OP217, its center is 9000 km below the centers of the rest of the heads. Apparently it was generated at a different part of the comet's head than other bands. A similar asymmetry was discussed in the case of Halley's comet in the paper already mentioned.

2. *Comet 1910 I (great comet).*—Because of the unfavorable weather and position of the comet only five measurable spectrograms

could be obtained between January 24 and February 11, 1910. The radiations were found to belong to the usual bands of cyanogen, $C+H$ and Swan.

The thermopile record of Plate OP252 shows a strong continuous spectrum of the solar type. CN IV is very strong and sharp on the continuous background. The record of Plate OP266 shows only one knot of C IV (Fig. 1, *b*).

Plate OP253, January 25, Spectrum plate, has to the red of C IV four knots whose wave-lengths approximately correspond to those of C III, the D lines of sodium (blended), C II and C I. The head of the comet in the D lines is especially sharp and bright; all other heads are fuzzy. On Plate OP262 of February 5 no trace of the D head is left; the knots of C IV, C III, and C II are very strong, but C I is absent; in view of this its identification with C I is not certain—it may belong to the unknown red bands associated in comets with the D lines.

The tail shows on several plates. It has a strong continuous spectrum, but the gaseous bands in it can be seen. They apparently belong to the Swan system. The D head did not extend far into the tail. The CN IV head was sharply defined on the side of the tail.

3. *Comet 1910 II* (*Halley*).—The spectrum of this comet was discussed in detail by the writer in the paper mentioned above.

4. *Comet 1910 V* (*Faye periodic*).—On Plate OP413, Seed 27, taken on November 11, 1910, the C IV knot is considerably brighter than CN IV. The spectrum consists almost wholly of the continuous background, apparently of the solar type and barely visible knots. The plate is weak and identification is uncertain. On the photograph the comet has a small tail. For this date $r=1.93$.

5. *Comet 1911 II* (*Kiess*).—Four plates (Seed 30) were obtained between July 9 and August 6, 1911. The wave-lengths indicate the usual radiation of CN, $C+H$, and Swan.

Figure 1, *c* shows marked changes in the intensity of the continuous spectrum as well as of different knots. C III is better developed on Plate OP440, where it is considerably brighter than the region of C V and CN III. On the following plate, OP456, it is almost equal in intensity to this region, and on Plate OP472 it is weaker.

The $C+H$ bands also underwent changes. They grew stronger

as the comet was receding from the sun. Being on July 9 ($r=0.73$) very weak in comparison with *CN* IV, they gradually became of the same intensity as *CN* IV on August 6 ($r=1.00$).

The continuous spectrum was of the violet type although the presence of the solar-type spectrum is noticeable in the earlier part of observation. The ultra-violet end of the spectrum was not strongly developed, as is clear from the comparison of the comet's spectrum with the spectrum of Algol.

Plate OP456, and especially OP440, shows an envelope around the *CN* IV head corresponding in shape and dimensions to that on the direct photograph. The comet had a large round head and a slender tail.

6. *Comet 1911 IV* (*Beliavsky*).—Five spectrograms were obtained on October 18, 19, and 20, 1911, exposure ranging from thirteen to thirty-two minutes. Since of the two published observations on the spectrum of this comet one[1] was made visually and the other[2] does not give the wave-lengths and both were made at an earlier date, I give here the measured wave-lengths in full: $\lambda\lambda$ 3883 (*CN* IV), 4026 ($C+H$), 4216 (*CN* III), 4366 (*C* V), 4556 (*CN* II), 4681 (*C* IV), 5021 (*C* III), 5437 (*C* II). All plates were Seed 30.

The microphotometric records (Fig. 1, *d*) reveal a strong continuous spectrum of the solar type. The great development and complete isolation of the *CN* IV band is striking (OP488). Two sharp heads between *CN* IV and *C* IV are *CN* III and *C* V. The $C+H$ group is very weak. The abrupt slope of the *CN* IV head on the violet side is a remarkable feature of this comet and shows absence of the ultra-violet radiations.

The tail is clearly visible on several spectrograms. It belongs apparently to the *C* IV band and other Swan bands. The *CN* radiations were restricted to the coma. The whole spectrum resembles very much that of another bright comet, 1910 I.

7. *Comet 1911 V* (*Brooks*).—Two spectrograms (Seed 27 and 30) of this comet were obtained on August 26 and September 24, 1911. The measurement of wave-length gave no new results compared to those published already by different writers. The microphotometer

[1] N. v. Konkoly, *Astronomische Nachrichten*, **190**, 42, 1911.

[2] W. H. Wright, *Publications of the Astronomical Society of the Pacific*, **23**, 269, 1911.

tracings (Fig. 2, *e*) show the $C+H$ bands very strong, but fainter than C IV and CN IV. The C III and CN V bands are almost absent. Apparently we have here a double spectrum of the solar and violet type. A small increase in brightness of C IV in comparison with the $C+H$ radiations when the comet approached perihelion is noticeable. The ultra-violet part of the spectrum was strongly developed.

8. *Comet 1911 VI* (*Quénisset*).—On the single plate OP480, secured on September 28, 1911, exposure forty minutes, three knots were measured at λλ 3883 (CN IV), 4024 ($C+H$), and 4700 (C IV). The C IV knot is much brighter than the other two.

9. *Comet 1912 II* (*Gale*).—Three spectrograms on October 1, 2, and 15, 1912, were obtained. The radiations of CN, $C+H$, and Swan were identified. A note on the spectrum of this comet was published by Parkhurst.[1]

The microphotometer records (Fig. 2, *f*) show the principal knots C IV stronger than CN IV. The continuous spectrum of clearly solar type at the beginning ($r=0.73$) changes into the violet type as early as October 15 ($r=0.76$).

This comet had two tails, one of the first Bredichin type, long; another of apparently third type, short. On the spectrograms both tails are visible, and both belong to the same radiation, C IV, which is in contradiction with Bredichin's theory.[2]

10. *Comet 1913 V* (*Giacobini periodic*).—On Plate OP587 taken on October 24, 1913, exposure sixty minutes, Hauff ultra-rapid plate, the knot CN IV is much brighter than C IV, but the rest of the spectrum is too weak for measurement.

11. *Comet 1913 VI* (*Westphal periodic*).—This periodic comet (period 61.7 years) was discovered at its return in 1913 by P. Delavan at La Plata on September 26, 1913, and was observed last on November 23, 1913. It was to pass perihelion on November 27, q being equal to 1.254. The spectrum of this comet has never been published.

Two plates were obtained by Parkhurst as shown in Table III.

The spectrum was the usual one, the wave-lengths being meas-

[1] *Popular Astronomy*, **20**, 605, 1912.

[2] This was noticed before F. Baldet's *Recherches sur la constitution des comètes* (1926) was published. Baldet has found the same thing on his spectrograms.

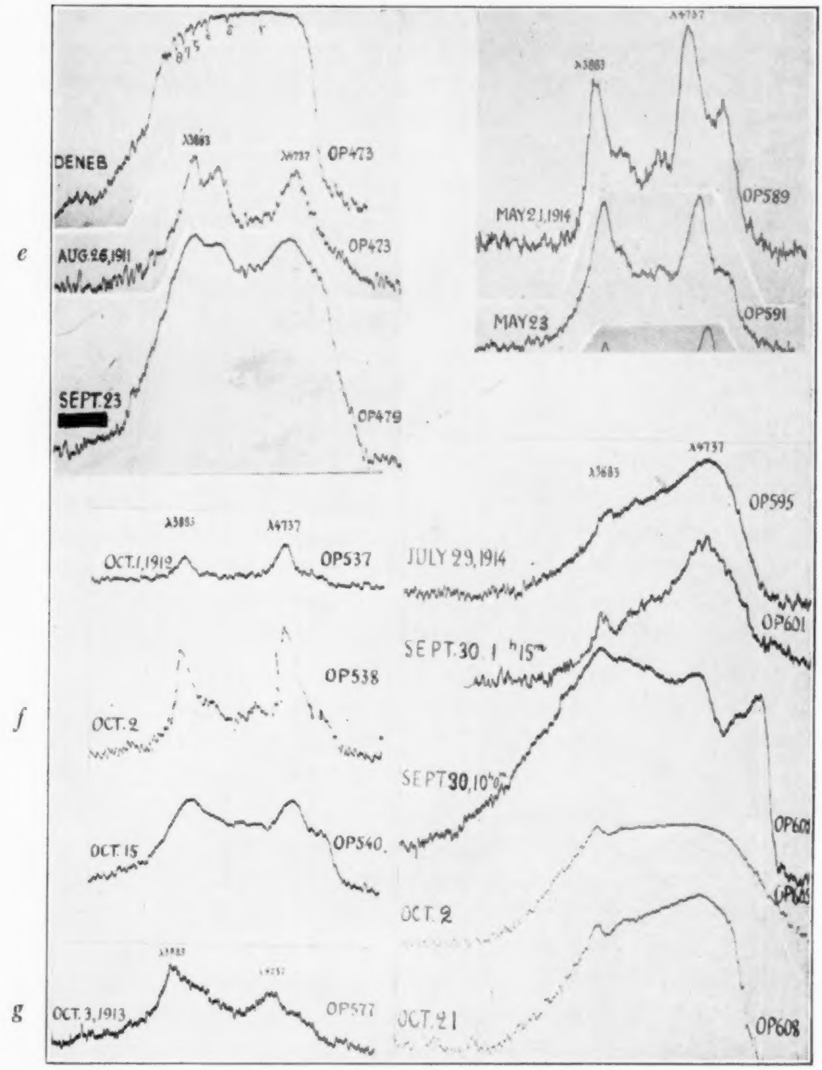

FIG. 2.—*e*, Comet 1911 V (Brooks)
f, Comet 1912 II (Gale)
g, Comet 1913 VI (Westphal)
h, Comet 1914 I (Zlatinsky)
i, Comet 1914 V (Delavan)

ured at λλ 3883 (*CN* IV), 4044 (*C+H*), 4264 (*CN* III), 4370 (*C* V), 4575 (*C* II), and 4695 (*C* IV).

The microphotometric record (Fig. 2, *g*) shows a continuous spectrum of the violet type. *CN* IV is much brighter than *C* IV, which is nearly equal in brightness to the *C+H* band.

This comet was discovered for the first time by J. G. Westphal in 1852 (IV). It did not then show any signs of unusual activity. In

TABLE III

No. OP	Date	Mid-Exposure	Exposure Time	Plate	*r*
575..........	Oct. 2	16^h40^m	25^m	Seed 30	....
577..........	Oct. 3	14 30	90	Seed 27	1.48

1913 it underwent striking transformations.[1] On October 4 its magnitude was 7.5; on October 11, 10.5; on October 28, 12.5; but on November 6 only a hazy spot of about fifteenth magnitude could be found in the comet's place. It was last photographed at Bergedorf on November 22 as an object of sixteenth or seventeenth magnitude, and on November 23 no traces of it were left. The comet was then approaching perihelion, and its theoretical magnitude on November 22 should have been ninth. This gives a decrease in brightness of about 8 mag.

The decline was gradual, probably beginning between October 4 and 11. Plates $442\frac{1}{2}a$ and *b*, obtained with the 10-inch and 6-inch Bruce telescopes by Barnard on October 3 with an exposure of four hours, show a round head with a strong condensation and a sharp bright jet in a position angle of 94°—that is, almost coinciding with the direction of the prolonged radius-vector. This jet is visible on the spectral plate OP577. It is in the same position-angle and can be seen attached to all the brighter knots, especially to *CN* IV. On the direct photographs a broad tail is barely visible in spite of the long exposure; its axis coincides with that of the jet.

Similar jets in this comet were described by G. Van Biesbroeck[2] in 1913, and by Hind[3] in 1852.

[1] J. Holetschek, *Untersuchungen über Kometen*, **5**, 46, 1917.

[2] *Annales de l'Observatoire de Belgique*, **13**, 600, 1914.

[3] *Astronomische Nachrichten*, **35**, 372, 1852.

12. *Comet 1914 I (Zlatinsky).*—Three spectrograms (Seed 30) of this comet were obtained on May 21, 23, and 27, 1914. They give the usual cometary spectrum of *CN*, *C+H*, and *C*. A short note on the appearance of the spectrum was published by Parkhurst.[1]

The intensity curves are represented in Figure 2, *h*. The continuous spectrum is of both the solar and the violet type. In the central part of the spectrum on Plate OP589 the continuous spectrum has the slope of the solar spectrum, while on Plate OP591 it runs in the opposite direction. The fluctuation in intensity of the *C+H* group compared with *C* III is also well shown.

On Plate OP591 the *CN* IV head has an envelope corresponding in size to that on the direct photograph 449*a* (Bruce 10-inch) of the same date.

14. *Comet 1914 V (Delavan).*—A detailed investigation on its spectrum as obtained at Ann Arbor was published by R. H. Curtiss and D. McLaughlin.[2] At the Yerkes the plates on Seed 30 emulsion shown in Table IV were secured.

TABLE IV

No. OP	Date, 1914	Mid-Exposure	Exposure Time	r	Photog. Density	
					CN IV	*C* IV
595	July 29	8^h46^m	40^m	1.78	0.75	1.55
597	Sept. 3	10 06	2	....	....	....
598	Sept. 5	8 25	10	....	1.72	2.40
599	Sept. 5	8 37	5	....	....	....
601	Sept. 30	1 15	10	1.19	0.98	2.04
602	Sept. 30	10 00	60	1.19	1.11	0.76
605	Oct. 2	9 55	50	1.17	0.70	0.90
606	Oct. 20	0 30	15	....	1.20	2.50
608	Oct. 21	0 30	60	1.11	0.78	1.33

The densities given in the last two columns were reduced to a standard exposure time of sixty minutes. They were not corrected for atmospheric changes because of the lack of data. For their reduction curves constructed for Seed 27 plates were used, so that only the general run of the spectral changes can be shown. A decrease of intensity of *C* IV on September 30 is well pronounced.

[1] *Ibid.*, **198**, 463, 1914.

[2] *University of Michigan Publications, Detroit Observatory*, **3**, 264, 1923.

The wave-lengths were measured as follows: λλ 3585 (*C* v), 3671(?), 3883 (*CN* iv), 4041 (*C*+*H*), 4228 (*CN* iii), 4448 (*C* v), 4623 (*CN* v), 4730 (*C* iv), 5048 (*C* iii), 5520 (*C* ii).

The intensity curves of the spectrum are represented in Figure 2, *i*. The most remarkable change occurred on September 30. On July 29 the continuous spectrum was of the solar type with the maximum of intensity at λ 4700. The same is true of Plate OP601, September 30, at 1^h15^m. But nine hours later, at 10^h, the spectrum changed completely. The violet and ultra-violet part of the spectrum on Plate OP602 very much increased in brightness, and the spectrum became of the violet type with the slope in the opposite direction. The Swan bands *C* iii and *C* ii became very strong while they were inconspicuous on Plate OP601. The intensity of the *C* iv band decreased considerably, as may be seen from Table IV. The *CN* iv band practically did not change in intensity. It was impossible to eliminate in this case the influence of the atmosphere, but probably both plates were affected in the same way as the altitude of the comet did not change much. The comet was at that time circumpolar, and the first plate was taken in the West while the second was taken in the East. No atmospheric disturbance could change the spectrum so radically.

Moreover, on the spectrogram No. 3008 taken at Ann Arbor only forty-two minutes earlier than OP602 a marked increase in the brightness of the violet part of the spectrum was recorded. Unfortunately, at Yerkes no direct photograph was made simultaneously, and the head of the comet is overexposed on the negatives of the preceding and the following days.

On Plate OP605, October 2, the violet part of the spectrum is still strong compared with the blue, but the spectrum approaches the solar type. On Plate OP608, October 21, the continuous spectrum is again of the solar type, practically the same as on July 28.

The comet possessed two tails, one long and straight, another short and wide. S. V. Orlow[1] has found that the straight tail belongs to the first type, while the short one belongs to the second. According to Bredichin's theory, these two tails should have two different spectra. Nevertheless, on the Yerkes spectrograms both tails have the same spectrum, apparently *C* iv. The dispersion is

[1] *Russian Astronomical Journal*, **1**, 72, 1924.

small but sufficient to show all details of the direct photograph reproduced in the spectral image.

14. *Comet 1915 II (Mellish).*—On Plate OP610, Seed 30, taken on March 17, 1915, exposure forty-three minutes, a very strong *CN* IV knot with a sharp nucleus was found. Its outer envelope corresponds in its dimensions to the envelope on the direct photograph 539*a* (Bruce). The comet had a large head and a slender tail. Usual cometary radiations were measured.

The microphotometer record (Fig. 3,*j*) shows a continuous spectrum of the violet type with a considerably developed ultra-violet part. The $C+H$ and C IV heads are of the same intensity. For this date $r=2.24$, $\Delta=2.00$, which indicates great luminosity of the comet.

15. *Comet 1917 I (Mellish).*—Plate OP649, Seed 30, March 22, 1917, exposure thirty minutes, gave a good spectral image. The following radiations were identified: λλ 3883 (*CN* IV), 4050 ($C+H$), 4216 (*CN* III), 4373 (C V), 4625 (*CN* II), 4720 (C IV), 516– (C III), 560– (C II).

CN IV has a sharp nucleus in an envelope corresponding to the outer envelope on the direct photograph 563*a* of the same date.

The intensity curve of the spectrum is given in Figure 3, *k*. It has the maximum in the violet. The ultra-violet part is almost absent.

16. *Comet 1921 V (Reid).*—Plate OP738, Ilford Panchromatic, secured on April 30, 1921, exposure thirty minutes, shows only one knot, *CN* IV, the Swan bands probably being weak.

17. *Comet 1924 II (Finsler).*—Two spectrograms were obtained on September 23 and 24, exposure thirty-five and thirty-two minutes, Seed 30. A note on its spectrum was published by Parkhurst.[1] The wave-lengths were measured by the writer as follows: λλ 3883 (*CN* IV), 4038 ($C+H$), 4221 (*CN* III), 4355 (C V), 4622 (*CN* V), 4702 (C IV), 5010 (C III).

The microphotometric records (Fig. 3,*l*) show the principal knots very well. There is considerable difference in the distribution of intensity on these two plates in spite of the short interval of time between them. On Plate OP752 the continuous spectrum has the maximum of intensity at C IV which is brighter than *CN* IV; the head C III is also brighter than the group $C+H$. On Plate OP753 these rela-

[1] *Popular Astronomy*, **32**, 521, 1924.

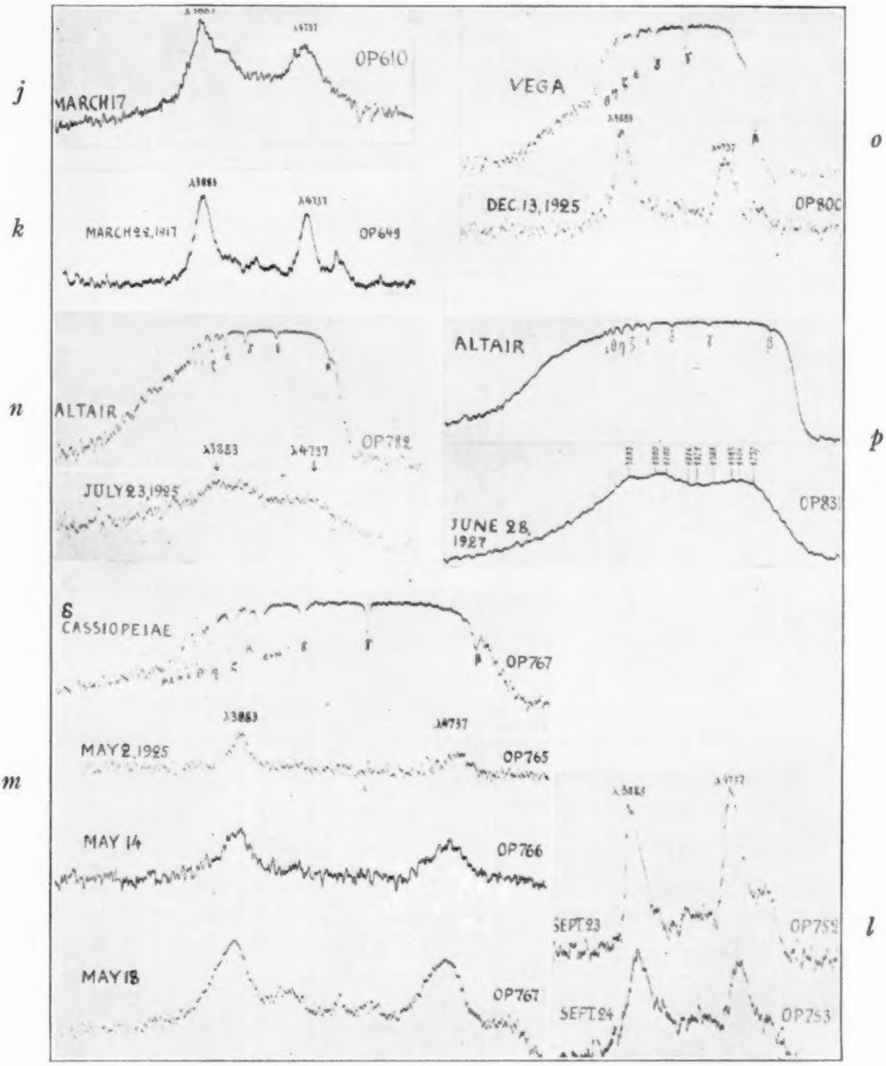

FIG. 3.—*j*, Comet 1915 II (Mellish)
k, Comet 1917 I (Mellish)
l, Comet 1924 II (Finsler)
m, Comet 1925*c* (Orkisz)
n, Comet 1925*d* (Tempel)
o, Comet 1925*k* (Peltier))
p, Comet 1927*c* (Pons-Winnecke)

tions are reversed and the continuous spectrum approaches that of the violet type. The comet was then rapidly receding from the sun. The ultra-violet part of the spectrum is weak. The knot *CN* IV consists of a sharp nucleus in a nebulosity which has the same size as the head of the comet on the direct photograph.

18. *Comet 1925c (Orkisz)*.—A report on its spectrum has been published by the writer.[1] Thirteen measurable spectrograms were obtained between April 28 and June 21, 1925.

The intensity curves of the spectrum of the comet taken with the 30° prism are reproduced in Figure 3, *m*. Almost the whole light of the comet was concentrated in the knots *CN* IV and *C* IV. The continuous spectrum was very weak on May 2, but became stronger by May 18. It was of the violet type, and the maximum of intensity at λ 4000 is well marked. The condensations *C* IV and $C+H$ are distinctly separated. The ultra-violet part is poorly developed.

19. *Comet 1925d (Tempel₂ periodic)*.—A note on its spectrum has already been published by the writer.[2] Five spectrograms were secured between June 19 and July 24, 1925.

The microphotometric record of Plate OP782, June 23, 1925, is given in Figure 3, *n*. It shows an intense continuous spectrum of the violet type on which the usual knots of *CN* and Swan project but slightly. The ultra-violet part is developed remarkably.

20. *Comet 1925j (Van Biesbroeck)*.—Only one measurable spectrogram could be obtained, OP793, November 21, 1925, 2^h30^m exposure, $30°+15°$ prisms, Hammer plate. It gives the *CN* IV and *C* IV condensations, *CN* IV being considerably the stronger of the two. The spectrum is partially blended with that of a star.

21. *Comet 1925k (Peltier)*.—Seven spectrograms of this comet were obtained, as described in Table V; the first three were on Hammer plates, the rest on Speedway.

The following wave-lengths were measured: λλ 3883 (*CN* IV), 4043 ($C+H$), 4210 (*CN* III), 4369 (*C* V), 4600 (*CN* II), 4695 (*C* IV), 5030 (*C* III).

The microphotometric tracings (Fig. 3, *o*) give a very faint continuous spectrum. On Plate OP797 it is practically absent. On Plate OP800 it has a feeble maximum in the violet. The two knots *CN* IV

[1] *Ibid.*, **33**, 417, 1925. [2] *Ibid.*, p. 638, 1925.

and *C* IV are well developed, but the rest are faint. That the ultra-violet spectrum is absent is clear from comparison with the spectrum of Vega.

22. *Comet 1927c (Pons-Winnecke periodic)*.—Seven spectrograms of this comet were secured by the writer and Mr. A. Pogo with the 30° prism from June 19 to June 28, 1927, all Speedway plates. The exposure time ranged from ten minutes to two hours and forty-five minutes. In view of the diffuse character of the cometary spectrum

TABLE V

No. OP	Date	Mid-Exposure	Exposure Time	Comparison Star	Prisms
794..........	Nov. 22	1^h39^m	68^m	....	15°+30°
795..........	Nov. 28	0 48	110	....	15°+30°
796..........	Dec. 7	1 32	50	....	15°+30°
797..........	Dec. 9	1 02	100	Vega	15°+30°
798..........	Dec. 10	0 17	15	....	15°
800..........	Dec. 13	0 37	75	Vega	15°
801..........	Dec. 17	0 20	60	Vega	15°

only approximate measurements could be made. Radiations λλ 3883 (*CN* IV), 4020–4100 (*C*+*H*), and 4630–4740 (*C* IV) were identified. On the microphotometer record traces of *CN* III, *CN* II, and *C* V can be seen (Fig. 3, *p*).

The peculiarity of this comet is the great development of the *C*+*H* band, which is the brightest and the largest of all monochromatic images. Next in brightness and size comes the *CN* IV band and then *C* IV.

The *C*+*H* and *CN* IV heads have bright jets which can be identified with the same jets on the direct photograph of the comet secured by Professor Van Biesbroeck with the 24-inch reflector.

The continuous spectrum is of the violet type. It is very strong and remarkably developed in the ultra-violet, resembling in this respect the spectrum of the comet $Tempel_2$ (1925).

23. *Comet 1927d (Stearns)*.—This comet was observed by Van Biesbroeck and the writer through the 40-inch refractor and a direct-vision spectroscope on May 2, 1927. It showed a characteristic band spectrum. Three bands were found in relative position and brightness corresponding to *C* II, *C* III, and *C* IV independently by both

observers. The nucleus, almost stellar, showed well in these bands. The continuous spectrum was strong. To the violet from the above-named bands was either a continuous spectrum or fainter bands. The same bands were observed by the writer on May 3 through the 12-inch refractor. They were estimated in brightness as *C* II-8, *C* III-10, *C* IV-7. An attempt to obtain the spectrum of this comet with a small camera and a 30° prism (exposure 2^h30^m) was not successful.

The heliocentric distance of the comet at that time was 3.7, probably the largest at which the spectrum of a comet has ever been observed.

DISCUSSION OF RESULTS

1. *Development of the spectrum.*—In the great variety of cometary phenomena there are features common to all comets. Such is the preponderance of the *CN* IV band when the comet is far from the sun and of the *C* IV band when it is near to the sun. This is not simply a change in brightness of these two bands, since their brightness is much influenced by the continuous spectrum.

There is a continuous spectrum due apparently to the intrinsic light of the comet which has the maximum of intensity at about λ 4000. We have called it the "violet-type spectrum." It is very bright in comparison with the spectrum of the reflected sunlight when the comet is farther from the sun than 0.7 astronomical units. It is very probable that this spectrum increases in brightness when the comet draws nearer to the sun but not so rapidly as the reflected solar spectrum. When the comet is nearer to the sun than 0.7 the reflected solar light is brighter than the intrinsic, and at a distance from 0.3 to 0.4 the intrinsic light is insignificant in comparison with the reflected. Table VI gives the results of investigation of the twenty-two comets observed photographically. The ninth column contains the type of the spectrum, "V" being the violet- and "S" the solar-type spectrum. The above-mentioned rule regarding the change of the continuous spectrum holds only approximately, as was to be expected. Two bright comets, Halley's and Delavan's, showed the solar spectrum when they were farther from the sun than the average. Otherwise Halley's comet behaved as it should according to the scheme, with its gradual development of the solar spectrum with the approach to perihelion and its subsequent weakening with

TABLE VI

No.	Comet	Name	q	Observed From r	Observed From Ph.-A.	Observed To r	Observed To Ph.-A.	Type of the Continuous Spectrum	Remarks
1	1908 III	Morehouse	0.945	1.37	46°	1.02	34°	V	....
2	1910 I	Great	.129	0.35	68	0.86	32	S	S weaker with increasing r
3	1910 II	Halley	0.587	2.18	18	1.46	36	V	*CN* IV is the strongest
				1.46	36	1.17	27	V and S	*CN* IV and *C* IV equal
				1.17	27	1.01	64	S	*C* IV is the strongest
				1.01	64	1.22	52	V and S	*CN* IV and *C* IV equal
4	1910 V	Faye	1.655	1.93	10	1.93	10	S (?)	*C* IV is the strongest
5	1911 II	Kiess	0.685	0.73	49	1.00	72	V	*CN* IV is the strongest
6	1911 IV	Beliavsky	.304	0.38	60	0.42	55	S	*C* IV is the strongest
7	1911 V	Brooks	.489	1.40	40	0.92	83	V and S	*CN* IV is the strongest
8	1911 VI	Quénisset	.788	1.13	57	1.13	57	V	*CN* IV is the strongest
9	1912 II	Gale	.716	0.73	68	0.76	60	V and S	*C* IV is the strongest
10	1913 V	Giacobini	0.977	1.00	73	1.00	73	V (?)	*CN* IV is the strongest
11	1913 VI	Westphal	1.254	1.48	29	1.48	29	V	*CN* IV is the strongest
12	1914 I	Zlatinsky	0.543	0.61	121	0.68	109	V and S	*C* IV is the strongest; weaker with increasing r
13	1914 V	Delavan	1.102	1.78	20	1.11	37	S	*C* IV is the strongest
14	1915 II	Mellish	1.005	2.24	27	2.24	27	V	*CN* IV is the strongest
15	1917 I	Mellish	0.190	0.80	63	0.80	63	V	*CN* IV is the strongest
16	1921 V	Reid	1.001	1.04	69	1.04	69	V (?)	*CN* IV is the strongest
17	1924 II	Finsler	0.406	0.63	105	0.65	100	V and S	*CN* IV and *C* IV equal
18	1925*c*	Orkisz	1.107	1.21	43	1.67	30	V	*CN* IV is the strongest
19	1925*d*	Tempel$_2$	1.315	1.32	32	1.32	32	V	*CN* IV is the strongest
20	1925*j*	Van Bies.	1.624	1.76	35	1.76	35	V (?)	*CN* IV is the strongest
21	1925*k*	Peltier	0.763	0.76	70	0.77	57	V	*CN* IV is the strongest
22	1927*c*	Pons-Winn.	1.040	1.06	60	1.05	35	V	*C*+*H* is the strongest; *CN* IV is stronger than *C* IV

the recession. The sudden recurrence of the violet spectrum in comet Delavan has been described above. An apparent exception is present in the comet 1910 V (Faye), but in view of its faintness it is impossible to say anything more definite.

Halley's comet at the heliocentric distance 2.2 and $Tempel_2$ at the distance 1.3 gave almost wholly a continuous spectrum of the violet type. This does not agree with the general opinion that when the comets are far from the sun they shine chiefly by reflected sunlight.

The continuous spectrum of both types must considerably influence the brightness of the cometary bands, and its elimination is difficult as we have seen in the case of Halley's comet.

With the facts at hand it is impossible to decide on the origin of the violet continuous spectrum. The hydrogen molecule which plays a prominent part in the formation of the Swan and $C+H$ bands has this kind of continuous spectrum. Many of the gases akin to those present in comets may produce continuous spectra with the maximum intensity in the violet. Such are CO and various organic hydrocarbons.[1]

The possibility of the Rayleigh scattering of the sun's rays by the molecules of the cometary head should also be taken into account. Some substances, notably sodium, in the state of vapor give a very sharp maximum of the scattered light in the deep violet.[2] However, it is difficult to explain in this way the existence of the cometary continuous spectrum of the violet type. Sodium appears in the comets in sufficient quantities to give bright lines when the comet is approaching the sun, that is, when the violet spectrum gives place to the solar. Moreover, on the theory of scattering, the regularity of appearance and disappearance of both types of the spectrum in spite of very different phase-angles of the comets would be unexplained. Table VI gives under heading "Ph.-A." the approximate values of phase-angles at which the comets were observed, that is, the angle at the comet between the directions to the earth and to the sun. We may note an apparent dependence of the type of the spectrum in the sense that small values of the phase-angles favor the

[1] W. Anderson, *Zeitschrift für Physik*, **38**, 535, 1926.

[2] Wood, *Physical Optics*, p. 624, 1919.

development of the violet-type spectrum. This would indicate a scattering effect. But at closer examination such correlation disappears. Halley's comet, for instance, had the solar spectrum sometimes at a smaller phase-angle than the violet. Comparison of different comets, such as Beliavsky and Mellish 1917, also leads to the same conclusion. The apparent correlation between the values of the phase-angles and the type of the spectrum may be easily explained by the fact that small values of r usually mean large phase-angles.

The spectrum of the comet depends apparently chiefly on its heliocentric distance; other parameters may play a subordinate part. Such are individual properties of the comet which may account for the variations in the spectra of different comets obtained at the same heliocentric distance. Several comets had a very sharp CN IV band with no traces of the spectrum to the violet of it. Such were comets 1910 I and 1911 IV (Beliavsky). Others had a remarkably developed ultra-violet spectrum like comet Morehouse. Comets 1925*d* (Tempel$_2$) and 1927*c* (Pons-Winnecke) had an almost wholly continuous spectrum of the violet type. The spectral knots in these comets were inconspicuous.

2. *Nucleus.*—Comparison of the direct photographs with the spectral images makes it possible to identify the spectrum of different parts of the comet. The nucleus proper emits all radiations, but even the smallest condensations on the nuclear line in the spectrum are larger than the nucleus on the direct photographs. This means that the nuclear radiations inclose the nucleus with a dense envelope, which is usually photographed on the spectral plate.

A peculiar feature of cometary activity embraces the jets, which are straight or curved streamers from the nucleus, usually very short and sharp, and quite distinct from the parabolic envelopes. Many of the bright comets of the last century displayed such jets. Especially notable in this respect was Halley's comet in 1835 and even as early as in 1682. Numerous observations of the jets during the apparition of 1910 of Halley's comet have been discussed by the writer elsewhere. Their spectrum was found to be gaseous with a preponderance of cyanogen even when the CN IV knot was weaker than C IV. The same has been found in comet 1913 *V* (Westphal). The only other observation on the spectrum of such a jet was made

visually by Young[1] for the comet 1881 I. He found it to be continuous. These jets apparently differ from the regular emissions forming the head of the comet only in the velocity of ejection, as is clear from the comparison of the spectrum of the envelopes with that of the jets. As we have seen, the emissions forming successive parabolic envelopes give principally the cyanogen and Swan spectrum. The radiations $C+H$ are restricted to some region between the nucleus proper and the inner envelope when the comet is near to the sun. When the comet is far from the sun $C+H$ is more uniformly distributed.

3. *Head.*—At large heliocentric distances the comet has a large round head, described by Bredichin[2] as the "atmosphere proper" (*eigentümliche Kometenatmosphäre*). If the tail is present in such cases it is short and slender, forming a bulb-shaped figure (*Zwiebelgewächs*) characteristic of many comets. In the present study comets 1911 II (Kiess), 1914 I (Zlatinsky), 1915 II (Mellish), 1917 I (Mellish), and 1924 II (Finsler) showed the bulblike shape. All of them had the atmosphere well developed in the *CN* IV band and hardly noticeable in the *C* IV band; *CN* IV had a sharp nucleus surrounded by a nebulosity, corresponding in size to the head on the direct photographs. The tail in all cases was too faint to be noticed on the spectrograms.

Apart from this atmosphere there occurs sometimes a halo around a comet that has already highly developed parabolic envelopes. A fine example of this kind is presented[3] by comets 1862 III and 1882 II. Halley's comet in 1835 also had a halo quite similar to that of 1910.[4]

In the case of Halley's comet we have found that the halo appeared suddenly, after some striking transformations had occurred in the nucleus, and that it disappeared gradually or became a part of the regular head of a bulblike shape. The same was observed in the above-mentioned comets.

We have found that the halo of Halley's comet probably had

[1] *American Journal of Science*, **22**, 135, 1881.

[2] Bredichin, *Mechanische Untersuchungen über Cometenformen*, von R. Jaegermann, pp. 173–178, 1903.

[3] *Ibid.*, pp. 175 and 195.

[4] *Memoirs of the Royal Astronomical Society*, **10**, 91, 1837, numerous drawings by Maclear.

cyanogen as its chief constituent. The perfectly round shape of the halo shows that its material was not subject to the repulsive force of the sun. The ordinary cyanogen bands also never extend far into the tail and in most cases are confined to the head alone. This may be connected with the fact that when Halley's comet was far from the sun and was of the bulblike shape cyanogen predominated both in intensity and extent in its spectrum. The extinction of the cyanogen bands in this comet after the explosion on May 24, 1910, may be interpreted as in interception of these emissions by a fresh supply of cyanogen from the head. When under the influence of the solar rays this new supply became active, not only the usual spectrum of the head was restored but the halo itself gave off the same rays. The whole process finds its analogy in the phenomena in the solar atmosphere when there occurs a difference in temperature between the successive layers of gas.

4. *Tail.*—An essential point of Bredichin's theory is that the tails of different types should have different spectra. But no hydrogen or metallic (except sodium) tail has ever been observed. On the other hand, there is direct evidence that comets having two tails simultaneously show the same spectrum in both tails. Such were comets 1912 II (Gale) and 1914 V (Delavan).

Moorehouse's comet gave for the tail exclusively the spectrum of CO^+ and N_2^+ group, and the comets Halley, Brooks (1911 V), and Daniel (1907 IV) had also strong CO^+ bands in the tails. However, the presence of the Swan bands in the tail of Halley's comet can hardly be denied. Furthermore, there were a number of bright comets having in their spectra no trace of the third negative group of carbon and possessing nevertheless long tails. Such were, for instance, comets 1910 I and 1914 V (Delavan). The Swan bands extending into the tail were noticed by many experienced observers. The presence of sodium was also observed throughout the comet.

In view of this, we may conclude that the tails of the comets consist of CO^+, N_2^+, C_2H_2 (Swan), and Na in different proportions. The presence of other gases in the tail cannot be demonstrated, and CN and $C+H$ certainly do not extend much beyond the coma.

5. *Origin of the cometary spectra.*—We have to consider here the following three factors which may produce a cometary spectrum: (*a*) the thermal action of the sun; (*b*) solar corpuscular emission, such

as α- and β-particles, neutral atoms, charged atoms; (*c*) direct influence of the sun's rays producing fluorescent phenomena.

a) The possibility of conversion of the solar radiant energy into the translational motion of the molecules evidently does not play a great part in the production of the cometary spectrum, except in the case of the comets with exceedingly small perihelion distance, like comet 1882 II. The necessary temperature, say 1000° C., would mean such a high average velocity of the molecules that the head of the comet would quickly dissipate. It is easy to show that with their small mass and enormous volume comets cannot retain the gaseous molecules even at a temperature of 0° C. The production of the spectrum under the influence of high temperature through intermolecular collisions may also be left out of consideration.[1] The probability of encounter is exceedingly small.

b) Emission of charged particles by the sun may play some part in the production of cometary spectra. However, it cannot explain all the facts. It is difficult to visualize the sun as emitting charged particles. To avoid these difficulties an ingenious theory of the emission of atoms of *He*, *Ca*, and other elements under radiation pressure, single or in a suite of electrons, was put forward by F. A. Lindemann, Milne, and others.[2] The theory is also intended to explain the phenomena of terrestrial magnetic storms and aurora borealis. All spectra occurring in comets may be produced in inert gases using low-speed electrons. This is in perfect agreement with the above-mentioned theory.

But there are other considerations. The terrestrial phenomena like aurora borealis are of a definitely localized character. Very often these displays affect only a small part of the earth. This is a natural consequence of the mechanism of emission as supposed by Lindemann and Milne. If we now turn to comets we find a surprising stability of their light and spectrum. The observed changes are far too rare and too small in comparison with the variation of the auroral displays, when complete darkness is followed by an intense illumination of the whole sky.

No periodicity of the cometary phenomena such as with aurora

[1] Franck and Jordan, *Anregung von Quantensprüngen durch Stösse*, p. 191, 1926.

[2] Numerous articles in *Monthly Notices*, 1924–1927.

borealis has ever been unquestionably demonstrated. The case of the bright and weak apparitions of Encke's comet, supposed by Berberich[1] and Bosler[2] to be connected with solar activity, was discredited by the thorough investigations of Holetschek.[3] He has shown that the alleged periodicity could easily be explained by conditions of the visibility of the comet.

Further difficulty with the theory of corpuscular bombardment is the extreme tenuity of the cometary atmosphere. In the laboratory no discharge can pass through the tube at a pressure below 10^{-5} mm unless inert gases are introduced. The density of the cometary tails is certainly much lower than 10^{-5} mm. The probability of the impact between the charged particles and the molecules of the tail must be very small.

The average life of an excited atom or molecule is of the order of 10^{-8} sec. It is clear that at the observed velocities of the particles of the tail the molecules of CO^+, for instance, ought to be under the action of the exciting agent along the whole tail. Such a constant agent can hardly be any corpuscular bombardment, as in the discharge tube, because in the case of the sun it is essentially discontinuous.

c) All difficulties of the corpuscular theory vanish in the case of fluorescence. It may be recalled here that Schwarzschild and Kron[4] in a paper on the brightness of Halley's comet came to the conclusion that only fluorescence can account for the observed facts.

One interesting consequence follows from this. The polarization observed sometimes in comets may be due to the influence of fluorescence. It was ascribed to the reflected sunlight without paying much attention to the plane of polarization. The question might be settled by observing polarization of the sodium D lines of emission in bright comets.

The question naturally arises whether all spectra observed in comets can be produced by means of fluorescence. It is known that many organic hydrocarbons, also oxygen, nitrogen, and metallic

[1] *Astronomische Nachrichten*, **119**, 49, 1888, and **131**, 76, 1893.

[2] *Bulletin de la Société Astronomique de France*, **23**, 443, 1909.

[3] *Untersuchungen über Kometen*, **4**, 44, 1916.

[4] *Astrophysical Journal*, **34**, 352, 1911.

vapors, when illuminated by white light give very complicated bands and a continuous spectrum. There is an indication that the Swan bands are a resonance system,[1] but nothing is known about cyanogen.

The direct influence of the solar rays may result also in the photoelectric effect. Under the light of sufficiently short wave-length ($\lambda < 3000$, A) many metals, such as iron, nickel, and other constituents of meteorites, give off electrons[2] which may ionize the cometary atmosphere.

Evidently in comets we have to do with very complex phenomena, and no simple scheme can account for them. The comets can reflect the sun's light without changing appreciably the curve of intensity of the solar spectrum. On the other hand, the presence of the violet-type spectrum shows that solar light can undergo considerable change in the comets, sometimes accompanied by violent outbursts. If the theory of fluorescence be true, comets in the last analysis depend in their luminosity on the sun and are intrinsically dark bodies.

YERKES OBSERVATORY
August 1927

[1] R. C. Johnson, *Philosophical Transactions of the Royal Society*, A, **226**, 188, 1927.

[2] S. C. Roy, *Proceedings of the Royal Society*, A, **112** 627, 1926.

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VOLUME LXVI NUMBER 5

THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

Edited by

GEORGE E. HALE
Mount Wilson Observatory of the Carnegie Institution of Washington

EDWIN B. FROST
Yerkes Observatory of the University of Chicago

HENRY G. GALE
Ryerson Physical Laboratory of the University of Chicago

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A New Old Testament

As advance accounts in the newspapers some time ago intimated, J. M. Powis Smith of the University of Chicago, Theophile J. Meek of the University of Toronto, Alex. R. Gordon of the United Theological College and McGill University, and Leroy Waterman of the University of Michigan, have completed their American Translation of the Old Testament. The excitement that the new version has caused in the daily press recalls that brought forth by the appearance of the Goodspeed translation of the New Testament four years ago.

While controversy rages the translators let the matter rest as stated in their Preface to the translation:

"Why should anyone make a new English version of the Old Testament? With the Authorized Version of King James and the British and American revisions, to say nothing of unofficial renderings, have we not enough? This question may quite fairly be asked. The only possible basis for a satisfactory answer must be either in a better knowledge of Hebrew, or in a fuller appreciation of fundamental textual problems, or in a clearer recognition of poetic structures, or in such a change in our own language as would render the language of the older translations more or less unintelligible to the average man of our day. As a matter of fact, our answer must be found in all of these.

"The most urgent demand for a new translation comes from the field of Hebrew scholarship. The control of Hebrew vocabulary and syntax available to the scholar of today is vastly greater than that at the command of the translators of the Authorized Version, or of its revisers.

"Modern studies of textual problems reinforce the need for a new rendering. . . . . The science of textual criticism has made great progress in recent years, and no translation of the Old Testament can afford to ignore its results. Our guiding principle has been that the official Massoretic text must be adhered to as long as it made satisfactory sense. . . . .

"Much of the text that has long passed as prose is now recognized as really poetic both in form and spirit. This adds to the necessity for a new translation. Poetry should not be printed as prose. The present translation brings into clear light many of the hidden beauties of Hebrew poetry. . . . .

"The English of King James's day is not wholly natural or clear to the average man of the present day. . . . . The use of 'vinegar' in the sense of a wine or liquor for drinking has long since ceased to be recognized. . . . . Facts like these make the reading of the Bible a scholarly rather than a religious exercise, and clearly point to the need for a new translation. . . . .

"The content of the Old Testament is, with little exception, on a high literary plane. The language of the translation, therefore, cannot be allowed to fall to the level of the street. In this translation the foregoing principles have been kept clearly in mind. It tries to be American in the sense that the writings of Lincoln, Roosevelt, and Wilson are American . . . . it aims at being easily understood wherever English is spoken. . . . .

"The translators and the University of Chicago Press have sought to give this translation the appearance of a modern book. This purpose has determined the make-up of the page and has led to the addition of headings for paragraphs, and to the *insertion of half-titles before* individual books. It has also kept verse numbers out of the text and relegated them to the margin. . . . ."

In the best tradition of modern English writing this new version interprets the impressive, eloquent Hebrew of centuries ago.

The following passage from "The Song of Songs, Which Is Solomon's" is illustrative of those sections which the translators have cast into poetic form:

THE MAIDEN TO THE YOUTH

Kiss me with kisses from your mouth,
for your love is better than wine;
the fragrance of your ointments is sweet;
Your very self is a precious ointment;
therefore do the maidens love you.
Take me along with you, let us hasten;
bring me, O king, into your chamber,
That we may exult and rejoice in you,
that we may praise your love more than wine;
rightly are you loved.

And here is a part of the story of Ruth in the new translation:

RUTH'S APPEAL TO BOAZ

Then her mother-in-law Naomi said to her,

"Should I not be seeking a home for you, my daughter, where you may be comfortable? Now then, what about our relative Boaz, with whose women you have been? See, he is going to winnow barley at the threshing-floor tonight. Wash and anoint yourself therefore, put on your best clothes, and go down to the threshing-floor; but do not let your presence be known to the man until he has finished eating and drinking. See to it, however, when he lies down, that you note the place where he lies; then go in, uncover his feet, and lie down yourself; he will let you know what to do."

"I will do just as you say," she responded.

So she went down to the threshing-floor, and did just as her mother-in-law had instructed her. When Boaz had eaten and drunk, and felt content, he went to lie down at the end of the grain-heap. Then she came in stealthily, uncovered his feet, and lay down. At midnight the man started up, and turning over, discovered a woman lying at his feet!

"Who are you?" he said.

"I am Ruth, your maidservant," she said. "Take your maidservant in marriage; for you are a near relative."

"May the Lord bless you, my girl!" he said. "This last kindness of yours is lovelier than the first, in that you have not run after the young men, either poor or rich. And now, my girl, have no fear; I will do all that you ask; for all the counselors of my people know that you are a fine woman. . . . ."

THE OLD TESTAMENT: AN AMERICAN TRANSLATION. Edited by J. M. POWIS SMITH. *Cloth $7.50, leather $10.00, postage 25 cents extra.*

Silly? Crazy? Damnable Heresy?

Since the appearance of his *Jesus: A New Biography*, Shirley Jackson Case has been heralded from the Atlantic to the Pacific by newspaper reporters as the arch-heretic of the century. Dr. Case, in attempting to show the modern reader "not the Jesus of the stained-glass window, but the Jesus who lived and walked with men," has, it seems, done something exceedingly sensational. The feeling of the publishers about the matter, however, has been expressed by the Nashville *Presbyterian Advance*, a by no means radical magazine, better than they could do it themselves:

"It appears that Professor Shirley Case, who has published several excellent volumes, has written a book on the life of Jesus. It is not yet published. [It has since appeared.] Some newspaper writer, however, learned something about the book and wrote a sensational story affirming that in the new book Dr. Case declares that Jesus did not affirm his own divinity. Whether this is a fact or not remains to be seen, but on the basis of the assertion of the 'exclusive story' (unfortunately the word 'exclusive' in such cases has come to have about the meaning of 'lying' to discriminating readers) other reporters got busy and interviewed some ministers. These ministers, without having seen the book, promptly proceeded to call it 'crazy' and 'silly' and at least two of them are quoted as calling it 'damnable heresy.' If there is

anything 'crazy' or 'silly' about the whole business, it is to be found in those persons who so violently denounce what they know absolutely nothing about, except on the 'say-so' of some untrained reporter who is probably unable to distinguish between theological dogmas and historical facts."

Hasty and popular as they are, entirely oblivious to the unique methods of scholarship upon which Dr. Case's biography rests, the newspaper accounts have nevertheless shown one significant thing: that the public is intensely interested in new interpretations of Jesus' life and work. The modern reader is eager to look back over the intervening centuries to Jesus as he actually was.

Professor Case has long been known as a scholar who has studied, more fruitfully, perhaps, than any other, the social background of early Christianity. His method has been his most original contribution. It has enabled him to bring the reader of today into direct contact with the environment of beginning Christianity. It enabled him to dispel in his *Historicity of Jesus* the recurring hoaxes that treat Jesus' existence as a myth. And it has now made it possible for him to bring the reader closer than ever before to the real Jesus of history, as he appeared to the men of his own time in Palestine over 1900 years ago.

Within the past few years there have been many unhistorical and sentimental lives of Jesus, but there has not been a biography dealing in so thoroughgoing a fashion with the results of scientific investigation.

JESUS: A NEW BIOGRAPHY. By Shirley Jackson Case. *$3.00, postpaid $3.15*.

The Ten Princes

Somewhere beyond the Himalaya Mountains lies Magadha, a land notorious for its unscrupulous delight in sensuous beauty and its ribald worldly wisdom. From this country, at a time when its people were gay, in love with poetry and pleasure, and shamelessly given to lying, fared Rajavahana and nine companion princes to conquer the four quarters of the universe. Dandin told the story of their adventures over a thousand years ago in *The Ten Princes*, his only prose novel. Arthur W. Ryder has retold it in a translation which retains the beauty of the original and adds a modern piquancy.

It seems that Rajavahana disappeared, and the nine companion princes, scattering to find him, met with a series of gay adventures in the course of which each gained a throne and an incredibly beautiful lady. Mr. Ryder's translation is a racy re-telling of Dandin's record, first of Rajavahana's experiences, and, as the other princes rejoin him, of their own exploits, related by them with appropriate flourishes and due exaggeration.

In these adventurers runs a pronounced strain of the picaresque. But rascals as they undoubtedly are, they must nevertheless be accredited with pleasant accomplishments. Handsome as no other mortals, erudite in ethics, astronomy, and metaphysics, they have a gift for the lute, are masters of magic, excel in horsemanship, and possess a scientific skill in thievery, gambling, and the arts of deception in general.

In their travels, they meet many beautiful maidens (versed in the arts of flirtation both major and minor), whom they charm by artifice and natural endowment, and describe in warm detail. And through their stories troop as great a crowd of shady characters, curious villains, and examples of shining virtues, as ever emerged from an oriental fancy: Buddhist nuns, unfaithful wives, sages, rakes, and kings, gay girls and gods, court ladies, merchants, thieves. Each has his appropriate philosophy which the princes remember to the last degree of subtlety, and readily report, whether the subject be the conduct of courtesans or the rules of political science.

Dandin was the master of a beautiful prose

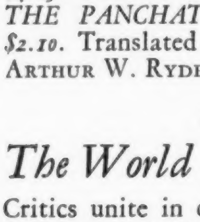
style which has not lost in the translating. One feature of his art is sententious brevity. He looked upon prose as a more exacting medium than poetry itself. Of his life we know little more than that he flourished in India in the seventh Christian century. *THE TEN PRINCES.* Translated by ARTHUR W. RYDER. *$2.00, postpaid $2.10.*

Arthur W. Ryder has also translated from the Sanskrit *The Panchatantra* and *Gold's Gloom.* Achmed Abdulla says of *The Panchatantra:* "Fairytales. But Fairytales for grown-ups. Fairytales suffused with a wisdom that is ironic, slightly bitter, wire-drawn, perfectly civilized. Mr. Ryder's translation is most excellent. It shows not only a thorough knowledge of the subject but understanding, sympathy, style, and a keen sense of humor."

Gold's Gloom is bound in exceptionally attractive form, with bright-hued covers, and a specially designed title-page and headbands by Preissig. The quintessence of the wisdom and charm of *The Panchatantra,* it is a representative selection of some of the most captivating stories in the world. *THE PANCHATANTRA. $4.00, postpaid $4.15. GOLD'S GLOOM: TALES FROM THE PANCHATANTRA. $2.00, postpaid $2.10.* Translated from the Sanskrit by ARTHUR W. RYDER.

The World and Man

Critics unite in calling *The Nature of the World and of Man,* by Sixteen Ranking Scientists of the University of Chicago, one of the finest and most engrossing popularizations of current science in existence. A handsome new edition, with bright-hued covers, has just appeared. In accordance with its authors' wish that it should always represent the most recent knowledge of science, revisions have been made throughout the book.



Forest Ray Moulton, the astronomer, says of the volume's theme: "The Nature of the World and of Man is not only a great subject—in fact, the greatest one that human beings may investigate—but it is one rich in romance and filled with stirring adventure. It will satisfy, if anything can, the love of youth for heroic things. The giants of mythological days are far surpassed by the huge machines that are the untiring slaves of modern men. The eye of the fabled Cyclops was not even prophetic of the great telescope on Mount Wilson, the pupil of whose eye, so to speak, is 100 inches in diameter. Not all the magic of antiquity can match the marvels of any chemical laboratory. Physicians cast out demons by means of surgery, by the use of extracts of ductless glands, and by prescribing chemical compounds, and if they have not raised the dead even in a single instance, they have at least within a few decades increased the average span of human life by ten or fifteen years. . . . . In fact, reason and the laws of nature (mark well *reason* and the *laws of nature*) have become a sort of intellectual telescope, as it were, with which modern science looks back across the geological ages. . . . ." *THE NATURE OF THE WORLD AND OF MAN.* By SIXTEEN RANKING SCIENTISTS OF THE UNIVERSITY OF CHICAGO. *$5.00, postpaid $5.15. (Textbook Edition $4.00, postpaid $4.15.)*

More Contemporary Americans

In his second series of appraisals of American life and letters, Mr. Boynton gives the reader an unusual view of public taste in America, a view marked by absence of ridicule and obloquy, in short, a glimpse of what American culture has to show on the positive side. The design of the book centers around the theme that certain fine inherited traditions are surviving, that the public is not oblivious to them, and that a new public is developing with a taste distinctly its own.

Beginning with Melville, Bierce, and Hearn, men who wrote before their time and who belong in spirit to the present

day, Mr. Boynton proceeds to Hergesheimer, Anderson, and Lewis. Believing that it is as necessary for the critic to see and declare what the artist is trying to express as for him to discuss the mode of expression, he conducts the reader to the very center of each artist's own particular world.

Various aspects of the American scene from Paul Whiteman and the movies to the college insurgents appear in a lively discussion that ranges freely over the seven arts and over the traditions and innovations of American life. *MORE CONTEMPORARY AMERICANS.* By Percy Holmes Boynton. *$2.50, postpaid $2.60.*

Some Contemporary Americans, Mr. Boynton's previous book, still retains its popularity. In it he interprets the drama, the short story, and the poet's art from his background of American life and tradition, and gives his personal reactions to the new modes, forms, and men.

Sandburg, Dreiser, Mencken, Robinson, Frost, Lowell, Wharton, Tarkington, Cabell, Cather, O'Neill, and Bradford appear in this brilliant and engaging series of estimates of contemporary American literature. *SOME CONTEMPORARY AMERICANS.* By Percy Holmes Boynton. *$2.00, postpaid $2.10.*

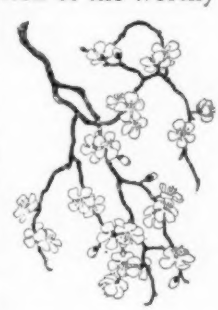
Chinese Painting

An extraordinarily beautiful volume with fifty-seven plates in collotype is *Chinese Painting* by John C. Ferguson. Chinese art as it really is and as it is valued by the country that fostered it is written into this book with authority and understanding.

Mr. Ferguson's qualifications for judging the art of China by Chinese standards—as it must be done—are many. For thirty-five years he has lived in China in close association with all the connoisseurs and critics of his day, who have been his guides in the examination of extant specimens of writing and painting.

Beginning with the earliest records of China, Mr. Ferguson has written the history of painting in that country to the eighteenth century. The introductory paragraph is characteristic of the spirit of the book:

"More than three hundred years ago Chang Ch'ou wrote in the Preface to his *Ch'ing-ho Shu Hua Fang* that he would like to be transferred into a bookworm, and promised that he would not injure any of the manuscripts or paintings in which he lived, but would be contented with mere existence in their company. Such was the delight with which one of the ablest critics of Chinese writings and paintings reveled in his enormous task of separating the good from the bad, the genuine from the false, among the accumulated ink-remains of previous generations. If Chang Ch'ou could have had his wish gratified by becoming a bookworm, he would not have been of that variety which Emerson placed in contrast with 'Man Thinking,' for he had a keen mind. His wish was the measure of his appreciation of the worthy writings and paintings that came under his observation. These were the products of man's soul and were quite unlike the work of man's hands in bronze or clay or jade. Through these writings and paintings Chang Ch'ou held communion with the spirits of the great artists and calligraphists who preceded him, and in their unseen world there were no limits of time or space." *CHINESE PAINTING.* By John C. Ferguson. *Boxed, $12.50, postpaid $12.75.*



Roosevelt

Turning aside from the hero-worship which has in the past been an almost unavoidable snare to biographers, however desirous of presenting Roosevelt as he actually was, Howard C. Hill has written a book which even at this late date shows Roosevelt in a new light.

The source material to which Mr. Hill has had access is more extensive than Roosevelt's biographers and historians have hitherto found available. Of this material, the most important part is the Roosevelt papers of the Library of Congress, to which only two or three others besides Mr. Hill have ever been given access. Although perhaps a quarter of his notes were censored by the official in charge, his book still includes the greatest amount of material that has ever been taken from this source.

Roosevelt the man, the creator of the Roosevelt myth, Mr. Hill would place before Roosevelt the statesman. Representative of Mr. Hill's view of Roosevelt in his official capacity is the following: "Rooseveltian imperialism as manifested in the Caribbean was opportunist in character, not planned or predetermined. Like the conscript fathers of ancient Rome, Roosevelt was led from one action to another by the swift current of events which during his administration seemed to change with kaleidoscopic rapidity. . . . . With each problem he dealt in the manner of a practical man of affairs rather than in the fashion of the doctrinaire or the man of predetermined policies."

The Boston Transcript comments, "We have Professor Hill to thank for a most interesting glimpse of our ex-President. . . . . He does not hammer away at his conclusions; he presents them gently. . . . . He invites us to strike a compromise, and therefore proves himself a most gracious gentleman, quite unlike any of his kind in the past or present. In his book we find for the student, an essay; for the interested reader, a narrative; for everyone, a striking portrait penned upon a background of living detail."

Harry Hansen in the *New York World* calls Mr. Hill's book "the sober second thought of the historian . . . . a very able study." And the *Herald-Tribune* says, "Professor Hill has turned the X-ray of historical criticism upon Roosevelt's Caribbean policy." *ROOSEVELT AND THE CARIBBEAN.* By Howard C. Hill. *\$2.50, postpaid \$2.60.*

The Forms and Motions of the Solar Prominences

By

EDISON PETTIT

This work is based on a study of solar prominences photographed with the Rumford spectroheliograph of the Yerkes Observatory.

To determine the character of movements and changes of forms of prominences, about four thousand plates were examined. Mr. Pettit analyzes and describes the many interesting types discovered, and discusses the probable nature of eruptive prominences. Eleven plates are included in the book.

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